JOURNAL OF DAIRY SCIENCE

THE JOHN CRERAR
JUL 20 1940
LIBRARY

Contents

Effect of heat and pH on the inactivation of rennin in whey. EARLE B. STRUBLE and PAUL F. SHARP 587

The relationship between the melting time of butterfat and its melting point. WILLIS D. GALLUP and A. H. KUHLMAN 593

Oxidized flavor in milk. II. The relation of oxidation-reduction potentials to its development. A. M. SWANSON and H. H. SOMMER 597

A comparative evaluation of an ice cream supply as it reaches the consumer. L. K. CROWE and P. A. DOWNS 615

The value of sodium metaphosphate in detergent mixtures in the cleaning of milking machines. W. L. MALLMANN, C. S. BRYAN and L. H. BEGEMAN 621

A review of oxidation in milk and milk products as related to flavor. W. CARSON BROWN and L. M. THURSTON 629

Report of the students' national contest in judging dairy cattle 687

Abstracts of literature A87

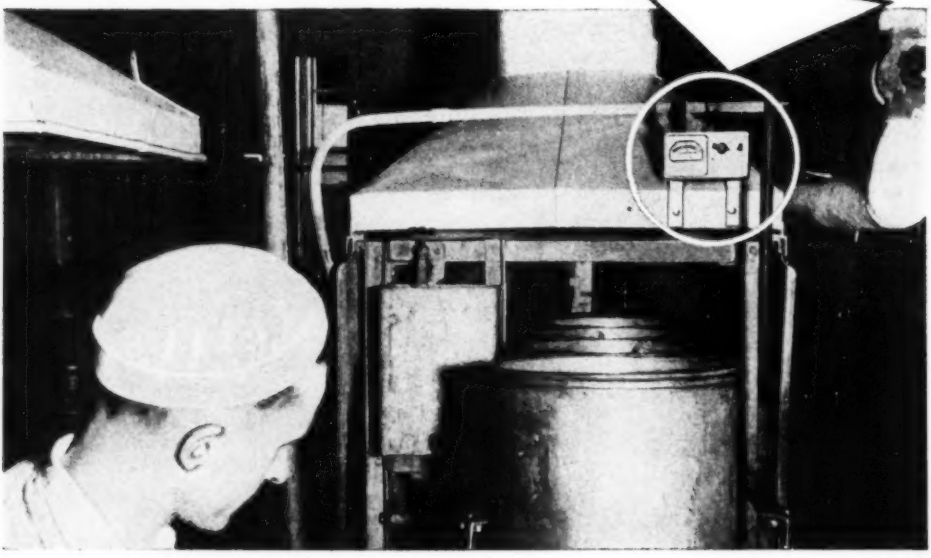
Vol. XXIII, No. 7, July, 1940

Published by the
AMERICAN DAIRY SCIENCE ASSOCIATION

Check and double check!

CAN WASHING SOLUTION STRENGTH

Wyandotte Can Wash Solution Strength Indicator —Part of the Servicing Equipment of Wyandotte Representatives.



IN can washing, nothing is more important than the cleaning solution. And now, for the first time, the operator has a visible test *and control* of the can washing solution strength!

With the electrically operated instrument shown above, your Wyandotte Representative can scientifically check the strength of your solution. Free of charge he will make this important test, help you select the most efficient Wyandotte can Washing cleaner, and make a periodic check to see that you are continuing to get the best can washing results at lowest cost.

A card will bring instant attention. *There is absolutely no obligation.* Write to The J. B. Ford Sales Company, Wyandotte, Michigan.

—FOR MORE PROFITS

Wyandotte makes a complete line of dairy cleaners. Cans, pipes, ALL equipment can be cleaned with Wyandotte products.

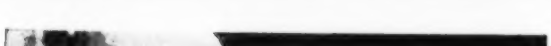
And after washing, use Wyandotte Steri-Chlor, in solution—an effective germicide, to destroy bacteria, protect your product, your equipment AND your customers.

Wyandotte

SERVICE REPRESENTATIVES IN 88 CITIES

THE J·B·FORD SALES CO· WYANDOTTE MICH·

Your advertisement is being read in every State and in 25 Foreign Countries



JOURNAL OF DAIRY SCIENCE

VOLUME XXIII JULY, 1940 NUMBER 7

EFFECT OF HEAT AND pH ON THE INACTIVATION OF RENNIN IN WHEY

EARLE B. STRUBLE AND PAUL F. SHARP

Department of Dairy Industry, Cornell University, Ithaca, N. Y.

INTRODUCTION

As a prerequisite to the study of some of the properties of para-casein, a study of the conditions under which the rennin could be inactivated immediately after the para-casein was produced was begun, so that materials in which the rennin had been inactivated would be available for study. The desirability of inactivating the rennin is evident from the demonstrations that it is involved in the ripening of cheddar cheese, and particularly in view of the evidence presented by Barthel, Sandberg and Haglund (1) that the rennin used to coagulate milk in cheese making remains active in the cheese for at least 8 months.

The present paper reports the results of experiments on the inactivation of rennin in whey in which advantage was taken of the destructive effect of heat and pH. The results point to conditions under which rennin could be inactivated with a minimum of alteration of the constituents of the milk, particularly the proteins.

Lörcher (5) in his extensive study of the effect of salts, acids and alkalies on rennin, found that alkalies were more destructive than acids. Numerous other workers have obtained similar results. Michaelis and Rothstein (8) concluded that the rate of destruction of rennin (from pepsin) could be expressed by the following equation:

$$-\frac{dx}{dt} = k\,x^{3/2}\,(OH)^{4}$$

Where x is the amount of rennin present at the time t, OH is the hydroxyl ion concentration and k is a constant. Experimental verification of the equation was limited to the region from pH 6.3 to 7.3. They concluded that peptic activity was destroyed at the same rate as the rennin activity.

König (4) and others have demonstrated that the concentration and environment of the rennin exert a profound influence upon the rate of its inactivation by heat.

EXPERIMENTAL

Milk was adjusted to pH 4.6 with normal HCl, the casein removed,

Received for publication April 28, 1939.

Copyrighted, 1940, by the AMERICAN DAIRY SCIENCE ASSOCIATION.

637.051
J82

652624

the whey heated for some time in a steam heated oven and filtered. Various amounts of HCl or NaOH were added to 200 ml. amounts of the clarified whey, the whey was warmed to the desired temperature, and 1 ml. of Hansen's commercial rennet extract was added. At 2, 6, 10, and 14 minute intervals samples of the heated whey were removed, quickly cooled and the pH was adjusted to 6.0 – 6.5, using brom cresol purple as an indicator. One ml. was then added to 20 ml. of milk held at 40° C. and the time required for the formation of flocks was recorded. Reconstituted dry skim milk was used to determine the coagulating time. Previous to its use for testing 2.5 ml. of $CaCl_2$ solution (378 grams of $CaCl_2$ per liter) was added to each 100 ml. of milk. The $CaCl_2$ lowered the pH of the milk from 6.57 to 5.68. After the whey was heated for 14 minutes its pH was determined at 25° C. The results are presented in figure 1 and table 1.

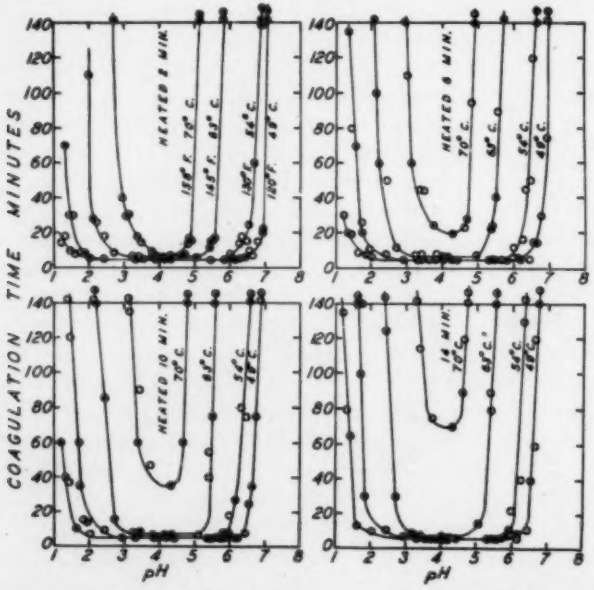


FIG. 1. Relation between temperature, pH and time of heating on the inactivation of commercial rennet extract heated in whey. The milk-coagulating power (time in minutes) of the whey after heating and cooling was used as the measure of inactivation.

The curves indicate a zone of maximum stability which centers at pH 4.0. The mid-line of the zone can be calculated from the data in table 1 by taking one-half the sum of each pair of values. The curves are nearly symmetrical with respect to an ordinate drawn through this pH. As the temperature of heating is increased and the time of heating is lengthened

TABLE 1

pH values, on the acid and alkaline side of the most stable zone, at which rennin activity was reduced 95 per cent by heating for the times and temperatures given. Below the acid and above the alkaline pH values given, inactivation of rennet is practically complete

Time of heating in whey	Temperature at which rennin was heated in whey							
	49° C. (120° F.)		54° C. (130° F.)		63° C. (145° F.)		70° C. (158° F.)	
	acid	alk.	acid	alk.	acid	alk.	acid	alk.
minutes	*pH*	*pH*	*pH*	*pH*	*pH*	*pH*	*pH*	*pH*
2	0.8	7.1	1.1	6.9	2.0	5.9	2.8	5.1
6	0.9	7.0	1.3	6.7	2.1	5.8	3.0	4.9
10	1.0	6.9	1.4	6.6	2.2	5.6	3.2	4.8
14	1.2	6.8	1.6	6.4	2.4	5.5	3.3	4.7

the zone of maximum stability (minimum coagulation time) is narrowed. The change from minimum destruction to complete destruction which occurs on both sides of the zone of maximum stability takes place within a pH range of about one unit. The coagulation time may change from the minimum time of about 7 minutes to no coagulation after several hours by an alteration of about one pH unit. Rennin was heated at pH 4.3 in whey for 2 minutes at 70° C. with practically no inactivation, but was completely inactivated at pH 5.3 or above by the same heat treatment. At the lower temperatures a broad zone of pH was found in which no appreciable destruction occurred in the time intervals studied. When inactivation due to altering the pH begins, the effect is a function of a rather high power of the altering H or OH ion concentration.

Arbitrary equations were developed which are in general agreement with the experimental data. When they were extrapolated to 25° and 0° C. the predicted and the experimental results did not agree satisfactorily. Apparently temperature, time of holding and pH do not bear the simple relationship to one another at 25° C. or below that they do at 50° C. and above.

The zone of maximum stability for rennin is usually given as considerably higher than pH 4.0. This difference may be due to various causes such as difference in the composition of the liquid in which the rennin is held, the time and temperature of heating, or the source of the rennin. Holwerda (3) found the maximum stability in 10 per cent sodium chloride and 2 per cent boric acid to be from pH 5.3 to 6.3. Michaelis and Rothstein (8) conclude that rennin is stable below pH 6.0. Van Dam (11) found that pH values near the neutral point were destructive and that the composition of the solution was important. Michaelis and Mendelssohn (7) concluded that the optimum pH for rennin action was about 6.0 to 6.4. Lundsteen (6) found the optimum pH to be 5.4.

In conjunction with determinations of the loss in milk-coagulating power of rennet, tests for pepsin activity were made using the method of Gützner (2). Professor Sumner (9) kindly supplied the Carmine-Fibrin. The original rennet showed only slight pepsin activity as indicated by this test. After the coagulation power of the rennet was destroyed, no pepsin action was indicated during 24 hours holding with the Carmine-Fibrin when compared with a heated blank. These results are in agreement with the observations of Michaelis and Rothstein (8) that alkalies destroy both the coagulating and the peptic power of the rennet, and with the observation of Tauber and Kleiner (10) that rennin can be prepared which possesses little pepsin activity.

Barthel, Sandberg and Haglund (1) in their tests of the milk-coagulating power of extracts obtained from cheese after various periods of ripening found that extracts from Swiss cheese did not coagulate milk, whereas extracts from cheese of other varieties possessed milk-coagulating power. Sweet rennet curd is heated in the whey to 50–60° C. in making Swiss cheese. The curd of Gouda, Cheddar and other types of cheese is usually heated to lower temperatures, and the maximum temperature is attained only after considerable acidity has developed in the curd as a result of lactose fermentation by the lactic acid-producing bacteria with which the milk is inoculated. The data in figure 1 are in agreement with the findings of Barthel, Sandberg and Haglund and indicate the rather narrow limits between the destruction of rennin in Swiss and its survival in Gouda cheese. Their findings for destruction of rennin in the curd are in agreement with ours for destruction of rennin in whey.

SUMMARY

The zone of maximum stability of the milk-coagulating power of commercial rennet extract, when heated in whey to 49° C. or above, centers at pH 4.0. The pH-inactivation curves at the temperatures of 49° to 70° C. are nearly symmetrical both above and below pH 4.0. In the regions where alterations in pH accelerate inactivation, an alteration of one pH unit includes approximately the complete inactivation effect.

No peptic activity could be demonstrated, using the carmine-fibrin test, in solutions in which the rennin activity had been destroyed.

The data indicate that normal amounts of rennet can be inactivated by holding at 50° C. for 14 minutes at pH 6.8 to 7.0.

REFERENCES

(1) Barthel, C., Sandberg, F., and Haglund, E. Undersökningar över förekomsten av löpe i ost. Medd. Centralanstalt. försöksäsendet jordbuks. No. 342, 1928.

(2) Grützner, P. Über eine neue Methode Pepsinmengen Colorimetrisch zu bestimmen. Archiv. f. ges. Physiol. 8: 452–459, 1874.

(3) Holwerda, B. J. Recherches sur la fabrication de la présure. Le Lait. 3: 765–777, 1923.

(4) KÖNIG, A. Untersuchungen über den Einfluss von Temperaturen auf Fermente, besonders von Lab und Pepsin. Biochem. Ztschr. 110: 266–286, 1920.
(5) LÖRCHER, G. Über Labwirkung. Archiv. f. ges. Physiol. 69: 141–198, 1897–1898.
(6) LUNDSTEEN, E. Über das Reaktionsoptimum des Chymosins. Biochem. Ztschr. 271: 259–263, 1934.
(7) MICHAELIS, L. UND MENDELSSOHN, A. Die Wirkungsbedingungen des Labferments. Biochem. Ztschr. 58: 315–328, 1913–1914.
(8) MICHAELIS, L. UND ROTHSTEIN, M. Die Zerstörung von Lab und Pepsin durch Alkali. Biochem. Ztschr. 105: 60–87, 1920.
(9) SUMNER, J. B. AND HOWELL, S. F. A qualitative test for enzymes of the trypsin and papain types. J. Biol. Chem. 109: 429–431, 1935.
(10) TAUBER, H. AND KLEINER, I. S. Studies on Rennin, I. The purification of rennin and its separation from pepsin. J. Biol. Chem. 96: 745–753, 1932.
(11) VAN DAM, W. Sur un défaut de la présure commerciale. Revue Générale du Lait. 7: 514–520, 1908–1909.

THE RELATIONSHIP BETWEEN THE MELTING TIME OF BUTTERFAT AND ITS MELTING POINT

WILLIS D. GALLUP AND A. H. KUHLMAN

Departments of Agricultural Chemistry Research and Dairying. Oklahoma Agricultural Experiment Station, Stillwater, Okla.

A rapid and convenient method for the determination of the melting time of butterfat was described in a previous paper from this laboratory (1). Essentially, the method is to determine the time required for a 25 ml. sample of butterfat at an initial temperature of 0° C. to melt and form a clear liquid when placed in a temperature-controlled water bath at 45° C. The test supplemented with hardness determinations (2) was designed for studying the "standing up" quality of butterfat at moderately high temperatures,—a quality which, despite its general commercial importance, has not been subjected to accurate measurement.

Several modifications of the proposed method appear possible, and would, no doubt, prove advantageous for routine work in which application of the test is made to fats and oils other than butterfat. For example, the temperature at which the melting time is to be determined might be raised or lowered in accordance with the melting point of the fat under investigation. Temperatures of 0° C. for chilling and 45° C. for melting have been found most suitable for butterfat. The melting time might be prolonged by substituting an air bath for the water bath. The latter change would be desirable in handling small samples of fat and an added convenience in observing changes of consistency during melting. Expression of results would necessarily need to be made in terms of a standard fat or oil having a constant melting time under the temperature conditions selected.

Chemical and physical constants, particularly the melting point, give some indication of the capacity of a fat to stand up at room temperatures. Occasionally, in the past, melting time has been studied by exposing standard blocks of butter or butterfat to a warm atmosphere and observing the condition of the samples at hourly intervals. This method of study, although capable of revealing marked differences between samples, especially when supplemented with photographic records, is time-consuming and does not allow for accurate measurement.

EXPERIMENTAL

In order to study the relationship between the melting time of butterfat and its melting point, melting time determinations have been carried out on a large number of samples having high, medium, and low melting points.

Received for publication November 24, 1939.

The possibility that melting time might be calculated with reasonable accuracy from melting point values, or vice versa, seemed likely.

The butterfat samples were handled in the usual manner, the butter being melted at 60° C., centrifuged and filtered, and kept in the dark in glass jars at 0° C. These samples were representative of the butterfat produced by individual cows of Ayrshire, Guernsey, Holstein, and Jersey breeds. The cows received experimental and control rations of varied composition. The melting point determinations were made according to the Wiley method as described in the A.O.A.C. methods (3). The melting time determinations were made according to procedures previously described (1).

RESULTS AND DISCUSSION

Table 1 gives the results obtained in which variations of 0.1° C. were allowed in melting point determinations and 15 seconds in the melting time determinations. These results are presented graphically in figure 1, in which average melting time is plotted against melting point.

The figures in table 1 show that there is considerable variation in the melting time of butterfat samples having the same melting point. In some instances this difference in melting time between samples amounts to over 3 minutes. This variation is greatest among samples having high melting points, 35°–37° C., and may be accounted for, in part, by the difficulties encountered in making accurate melting time determinations at a temperature only slightly above the melting point of the sample (1). The last column of table 1 gives the values obtained when the average melting time in minutes, is subtracted from the melting point, in degrees C. It is noteworthy that these values which fall between 20.2 and 21.5 vary only slightly, the average value being 21.1.

TABLE 1

Melting time of butterfat samples having melting points between 30.2° C. and 37.5° C.

Number of samples	Melting point	Melting time			Difference*
		Minimum	Maximum	Average	
	°C.	min.	min.	min.	
3	30.2	9.00	9.25	9.00	21.2
3	31.0	9.00	10.25	9.50	21.5
3	31.3	9.25	10.75	9.75	21.5
4	31.7	9.50	10.75	10.25	21.5
7	32.3	10.75	11.50	11.25	21.0
8	32.5	10.50	12.00	11.25	21.2
5	33.0	11.00	12.50	11.75	21.2
9	33.5	11.00	13.25	12.25	21.2
6	34.0	12.75	13.25	12.75	21.2
10	34.5	12.75	14.50	13.50	21.0
19	35.3	13.25	16.75	14.75	20.5
11	35.6	14.00	16.75	15.00	20.6
8	36.5	14.25	17.50	16.25	20.2
4	37.5	15.50	18.75	17.25	20.2

* Melting point in degrees C. minus average melting time in minutes.

It appears, therefore, that the melting time of butterfat may be estimated from melting point data,—in the present experiment, by subtracting 21.1 from the melting point. The melting time may be more closely approximated by use of the curve in figure 1, the points on the curve representing average values taken from table 1. Only two points, those at 32.3 and 32.5° C. lie outside the smoothed curve.

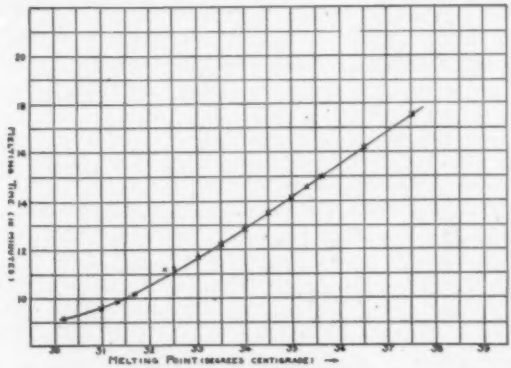


FIG. 1. Curve showing relation between melting point and melting time.

The foregoing discussion is made with full knowledge that the calculations are applicable only to melting time data secured under the experimental conditions as previously described (1). There is reason to believe that any change in these conditions which might effect a change in melting time would not alter the order of the results and that a direct relationship between melting point and melting time would still be evident.

SUMMARY AND CONCLUSIONS

Determinations were made of the melting time of butterfat samples having a wide range of melting point values.

Melting time was found to be roughly proportional to melting point.

Under the experimental conditions employed, the average melting time (expressed in minutes) of all samples was between 20.2 and 21.5 points lower than their actual melting points (expressed in degrees C.).

By means of a curve the melting time of butterfat samples can be closely approximated from melting point determinations.

REFERENCES

(1) GALLUP, W. D., KUHLMAN, A. H., AND WALDBY, R. M. Variations of certain chemical and physical properties of butter fat as revealed by melting time. Oil and Soap, 14: 124–126. 1937.

(2) GALLUP, W. D. Studying the hardness of butter fat. Apparatus and routine procedure. Ind. and Eng. Chem., Anal. Ed., 8: 123–124. 1936.

(3) Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists. Ed. 4, 710 pp., illus. Washington, D. C. 1935.

OXIDIZED FLAVOR IN MILK: II. THE RELATION OF OXIDATION–REDUCTION POTENTIALS TO ITS DEVELOPMENT

A. M. SWANSON AND H. H. SOMMER

Department of Dairy Industry, University of Wisconsin, Madison, Wisconsin

The development of oxidized flavor in milk is now assumed to be caused by certain oxidative changes taking place in the milk. Generally it has been believed that butterfat is the constituent in milk which has undergone oxidation on the development of the oxidized flavor. Findings from recent research tend to substantiate the belief that oxidized flavor in milk which has been catalyzed by copper results from oxidation of the phospholipids present in the milk. Since oxidized flavor results from oxidative changes, oxidation-reduction potentials should give valuable information in the study of this problem. Oxidation-reduction potential measurements have been applied by previous workers with various degrees of success. The work reported herein was conducted to further apply oxidation-reduction potential studies to the problem of oxidized flavor in milk and milk products.

REVIEW OF LITERATURE

Thurston, Brown and Dustman (16) were the first to suggest that oxidized flavor in milk results from the oxidation of lecithin. Brown, Dustman and Thurston (1) found no appreciable differences in iodine numbers of butterfat from normal and oxidized milk. Swanson and Sommer (14) found a marked decrease in the iodine number of the phospholipid fraction of milk on the development of oxidized flavor but found no significant difference in the iodine numbers of butterfat from normal and oxidized milk. The above findings suggest that the phospholipid fraction of milk plays an important part in the development of oxidized flavor.

Gebhardt and Sommer (5) in 1930 found that there was a marked increase in the oxidation-reduction potential of milk when it was agitated with copper blades. Morris and Sommer (10) in 1932 obtained results which showed that the keeping quality of cream is poorest in samples having the highest oxidation-reduction potentials. These workers added a reducing agent, sodium sulphite, to the cream and prevented oxidation.

In 1933 Tracy, Ramsey and Ruehe (17) observed a definite relationship between the oxidation-reduction potential of milk and cream and the development of oxidized flavor on the addition of copper. The addition of copper caused a marked increase in the oxidation-reduction potential. Thurston (15) in 1935 reported on the influence of different metals and metallic salts on the oxidation-reduction potentials of milk. Stannous chloride, stannic chloride and aluminum chloride caused a decrease in the

Received for publication November 30, 1939.

oxidation-reduction potentials of milk at a faster rate than in the control samples. Iron powder and ferric chloride caused a slight increase in potential. Ferrous chloride immediately after addition to milk caused an increase in potential, but this potential soon decreased to approximately the same potential as the control. Cuprous chloride caused the greatest increases in oxidation-reduction potentials.

Greenbank (7) found copper to be the most effective catalyst in producing oxidized flavor in milk. Ferrous iron also catalyzed the flavor development but larger quantities were required to produce the same results. Ferric iron was not very effective in producing the oxidized flavor. Greenbank suggests that ferric iron, which is an oxidizing agent, is an inhibitor to this flavor development.

In 1937 Webb and Hileman (21) reported on their studies in which they used a vacuum tube potentiometric circuit for measuring oxidation-reduction potentials. These workers found that oxidized flavor in milk is due to or accompanied by an increase in oxidation-reduction potential, but this increase is not proportional to the concentration of added copper. Working with individual cows, they found that there is no relationship between oxidized flavors and oxidation-reduction potentials of milk.

Brown, Thurston and Dustman (2) added copper to raw milk, to milk before pasteurization and to milk after pasteurization. They found that raw milk and milk with copper added after pasteurization developed a more intense oxidized flavor, the suggested explanation being that some of the copper may combine with the proteins during the pasteurization process and is no longer free to catalyze the reaction.

Sharp, Trout and Guthrie (13) found that contamination of milk with copper caused destruction of vitamin C, and that there is a positive correlation between the rate of oxidation of ascorbic acid and the development of oxidized flavor. They also state that the holder method of pasteurization at 143–145° F. for 30 minutes does not appreciably accelerate the destruction of ascorbic acid.

Turgeon, Stebnitz and Sommer (19) worked on the Ritter's test as a means of determining copper contamination. Both the vitamin C and the copper content of the milk affected the results of the Ritter's test. They found that the vitamin C content was quite uniformly reduced to 7 milligrams per liter at the time of first color change and reduced to zero by the time the color was definitely developed.

Chilson (3), Dahle and Palmer (4) and Greenbank (7) have all reported that the addition of 50 to 100 milligrams of pure crystalline ascorbic acid to milks which develop oxidized flavor spontaneously will prevent the flavor defect.

In Central Europe electrical treatment of milk has been used as a means of neutralizing developed acidity in milk and cream. Winkler (22)

discusses an electro-neutralization process in which milk is subjected to the action of direct current. Gratz (6) also has discussed the process. Electrodes are placed in a vessel of non-conducting material. Milk enters the vessel at the bottom, flows between the electrodes, which are placed either in a vertical or horizontal position, and leaves through an overflow at the top. The process is covered by Austrian and Italian patents. Pien and Baisse (11) discuss the theory of electrical deacidification. Sodium liberated at the cathode neutralized the lactic acid, and the chlorine which was liberated at the anode combined with the protein. Woljagin and Scheimpflug (23) carried on electrical deacidification by means of electrodialysis. Milk was placed in the cathode chamber and whey in the anode chamber with a clay diaphragm separating the liquids.

EXPERIMENTAL PROCEDURES

Since milk is a poorly poised system, a vacuum tube potentiometer circuit was made and used in conjunction with a Leeds-Northrup portable potentiometer. The vacuum tube potentiometer circuit was made according to plans furnished by Johnson (8). Platinum electrodes similar to those of Webb and Hileman (21) were used.

Difficulty was experienced in getting the electrodes in a sample of milk to check. Previous workers have also experienced the same difficulty. Closer checks between electrodes were obtained when extreme care was taken in their cleaning. The electrodes were first placed in boiling trisodium phosphate solution and then in hot chromic acid solution, remaining in each solution for a period of from one-half to one hour. The electrodes, after being removed from the chromic acid solution, were thoroughly rinsed and placed in distilled water from eight to twelve hours before using.

Two hundred-and-fifty-cc. brown glass bottles were used as electrode vessels. Each bottle was fitted with a cork stopper through which three holes were drilled. Two electrodes and a saturated potassium chloride agar bridge were placed into each sample of milk. A series of eight bottles were then connected to a saturated calomel half cell.

Milks from individual cows were obtained from the University herd. Aluminum pails were used for milking and the milk was brought to the laboratory in either aluminum pails or brown glass bottles. Extreme care was taken to prevent copper or iron contamination. The milk was taken to the laboratory and pasteurized within two hours after milking. Pasteurization was conducted in aluminum beakers with aluminum stirring devices. Heating was carried out in water baths which were connected to a steam line for heating and thermo-electrically controlled for holding at pasteurization temperatures. Immediately after pasteurization the containers were moved to a cold water bath for cooling.

The milk samples were then set up by adding the catalyst, and in some experiments anti-oxidants were also added. The samples were then placed in a refrigerator and allowed to stand with the least amount of handling possible. Duplicate samples were put in 500-cc. brown glass bottles and placed in the refrigerator along with the electrode vessels. These samples were used for vitamin C titrations and then observed at the end of the storage period of 60 to 72 hours for the development of oxidized flavor.

Oxidation-reduction potential readings were taken at short intervals during the early stages of the storage period and then taken at longer intervals after twenty-four hours of storage. The oxidation-reduction potential readings were then converted to Eh. The values for the E.M.F. of a calomel half cell at different temperatures were obtained from data by Vellinger (20).

Trout and Sharp (18) report that the temperature of 21° C. appeared to be more satisfactory for judging milk for oxidized flavor than did the temperature of 35° C. After storage the samples were warmed up to 21° C. and were always examined by at least two judges who were familiar with oxidized flavor. The following system was used for recording the presence of oxidized flavor and its intensity:

++++ = very strong oxidized flavor.
+++ = strong oxidized flavor.
++ = distinct to pronounced oxidized flavor.
+ = slight oxidized flavor.
± = doubtful oxidized flavor.
− = no oxidized flavor.

The method of Kon and Watson (9) was used in this work for determining the reduced ascorbic acid content of milk. The milk proteins and fat were precipitated with 20 per cent tri-chloroacetic acid. An exact quantity of filtrate was then titrated with 2:6 dichlorobenzenoneindophenol. The dye was standardized against crystalline ascorbic acid. In this work the water used was re-distilled in an all-glass distilling apparatus.

Influence of metal on oxidation-reduction potentials and the development of oxidized flavor

Pasteurized milk from an individual cow was used in preparing the samples for this experiment. A copper sulfate solution was prepared so that one cc. of solution added to one pint of milk would give a copper concentration of 0.5 parts per million parts of milk. Ferric sulfate and ferrous sulfate solutions were made up to such concentrations that one cc. of solution added to one pint of milk would give 5 parts of iron per million parts of milk.

Copper was added at concentrations of 0.0, 0.25, 0.5, 1, 2 and 5 parts per million parts of pasteurized milk. Ferric iron and ferrous iron were added

at concentrations of 0, 5, 10, 25 and 50 p.p.m. The changes in O–R (oxidation-reduction) potentials were followed, and at the end of 72 hours the samples were examined for oxidized flavor.

A similar experiment was conducted on a sample of mixed herd milk. The results of the two experiments were compared to determine the difference in susceptibility of the two milks to oxidized flavor development.

Time of copper addition to milk

Copper in the form of copper sulfate solution was added to milk before and after pasteurization at a concentration of 1 p.p.m. Two series of samples were prepared and kept in a water bath at 10° C. for 15.5 hours. Electrodes were placed in one series, and from the other series, samples were taken for reduced ascorbic acid determinations. O–R potential readings and ascorbic acid titrations were made at short intervals.

Copper addition to whole milk, skimmilk and cream

A mixed sample of milk was pasteurized in an eight gallon aluminum milk can and then separated. Samples of whole milk, skimmilk, 20 per cent cream and 29 per cent cream were prepared with and without added copper. Two parts of copper per million were added. Potential measurements were made during the storage period, and at the end of 72 hours all samples were examined for oxidized flavor.

A study of milk from individual cows

Milks were obtained from four individual cows. Two of these cows were Holsteins and the other two were Guernseys. Each lot of milk was pasteurized separately and then divided into two parts. To one part, copper was added at a concentration of 2 p.p.m. and to the other part no metallic catalyst was added. Samples were then prepared for O–R potential measurements and for ascorbic acid determinations. The samples were stored at 4° C. for 72 hours and at the end of this period they were examined for the presence of oxidized flavor. During the storage period O–R potential measurements and reduced ascorbic acid determinations were made at regular intervals.

Ascorbic acid as an anti-oxidant

Crystalline ascorbic acid and crystalline d-isoascorbic acid were added to pasteurized milk to study the effect on O–R potentials and the development of oxidized flavor. Pasteurized milk was divided into three lots. To one lot 100 mgs. of ascorbic acid per liter of milk was added, to another 100 mgs. of d-isoascorbic acid per liter of milk, and the other lot was left as the control. Then each lot of milk was divided in half and to the one half 3 p.p.m. of copper as copper sulfate was added. Oxidation-reduction po-

tential measurements and titrations for reduced ascorbic acid were made at regular intervals during storage. At the end of 60 hours the samples were examined for the presence of oxidized flavor.

Change in oxidation-reduction potentials caused by electrical current

Electricity was passed through milk as a means of changing the O–R potential. A glass chamber was constructed, using a 1.5″ by 8″ glass test tube with a milk capacity of 95 cc. Milk was allowed to flow into the chamber from below and carried out by means of a side-arm connection. Two platinum electrodes, 0.5″ by 2.0″, were placed within the chamber. A porous clay thimble was also placed in such a position that it would extend down into the milk. Inside of the thimble was placed a dilute solution of sodium chloride and a carbon electrode. The sodium chloride solution was continuously replaced by fresh solution. Dry cells were used as the source of the electrical current. For the work reported herein, a current of 24 volts and 0.4 amperes was used. Milk was passed through the chamber at the rate of 155 cc. per minute.

In the first series of the experiment, milk was passed through the apparatus without any current flowing. In the second series, the platinum electrodes were negative and the carbon electrode in the salt solution was positive. In the third series, the platinum electrodes were positive with the carbon electrode negative. In the last series the clay porous thimble was removed and one of the platinum electrodes was positive and the other negative. Two samples of mixed milk were set up from each series. Copper in the form of copper sulfate solution was added to one of the series at concentrations of 2 p.p.m. Potential measurements were made and after 72 hours the samples were examined for oxidized flavor.

EXPERIMENTAL RESULTS

All of the oxidation-reduction potential measurements were made with two electrodes in each sample of the milk. The potential readings from the two electrodes were averaged, and this average was taken as the potential for each reading time. The results from each series of experiments were tabulated and from these data the following graphs were drawn.

Influence of metal on oxidation-reduction potentials and the development of oxidized flavor

Figure 1 gives the results of the different concentrations of copper in the form of copper sulfate on the O–R potentials of milk from an individual cow. Copper caused a considerable increase in the O–R potential. The increase in potential was slower and not as great with the lower concentrations of copper. The rise in potential was not in proportion to the concentration of added copper. When the potential had reached its maxi-

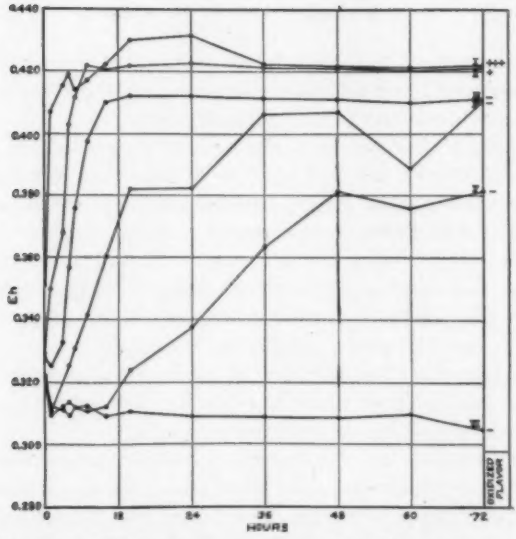


FIG. 1. The effect of different concentrations of added copper on oxidation-reduction potentials of milk and the development of oxidized flavor.

I—5 parts per million of added copper.
II—2 parts per million of added copper.
III—1 part per million of added copper.
IV—0.5 part per million of added copper.
V—0.25 part per million of added copper.
VI—0 part per million of added copper.

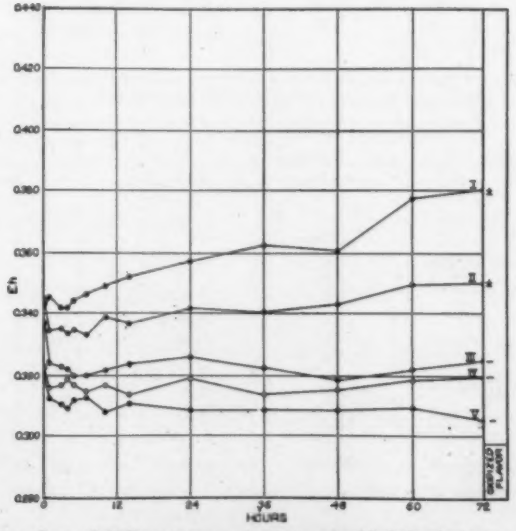


FIG. 2. The effect of different concentrations of added ferric iron on the oxidation-reduction potentials of milk and the development of the oxidized flavor

I—50 parts per million of added ferric iron.
II—25 parts per million of added ferric iron.
III—10 parts per million of added ferric iron.
IV— .5 parts per million of added ferric iron.
V— 0 parts per million of added ferric iron.

mum point, it continued to remain fairly constant at this high level. With the lower concentration of added copper and with the control, there was a marked decrease in potential during the first hour.

The addition of ferric iron in the form of ferric sulfate, as shown in figure 2, does not cause a rapid increase in potential like the addition of copper. There was a small gradual increase in potential during the entire storage period. The increase was greater with the higher concentrations of ferric iron. Only in the concentrations of 25 and 50 parts per million of ferric iron was there a slight resemblance of oxidized flavor. Ferric iron added at the rate of 50 parts per million did not affect the potentials any more than did 0.25 parts per million of copper.

Figure 3 shows that the addition of ferrous iron to milk caused a decrease in potential. These results are in keeping with the property of ferrous sulfate because it is a reducing substance.

Table 1 summarizes the effectiveness of copper, ferric iron and ferrous iron in catalyzing the development of oxidized flavor in mixed milk and milk from an individual cow. The mixed milk was more susceptible to the metallic catalyst than was the milk from the individual cow. In both cases ferric iron caused little oxidized flavor while the same concentrations of ferrous iron were very effective.

Time of copper addition to milk

Copper added at concentrations of one part per million to a sample of milk from an individual cow before pasteurization had catalyzed the oxida-

TABLE 1

The effectiveness of different metals in catalyzing the oxidized flavor in a sample of mixed milk and a sample of milk from an individual cow

Catalyst	Concentration of catalyst	Source of milk	
		Individual cow	Receiving tank
	p.p.m.		
Copper in form of copper sulfate	0.0	−	−
	0.25	−	±
	0.5	−	+
	1.0	−	++
	2.0	+	++++
	5.0	+++	+++++
Ferric iron in form of ferric sulfate	0.0	−	−
	5.0	−	−
	10.0	−	−
	25.0	±	±
	50.0	±	±
Ferrous iron in form of ferrous sulfate	0.0	−	−
	5.0	±	++
	10.0	+	++
	25.0	++	+++
	50.0	++++	+++++

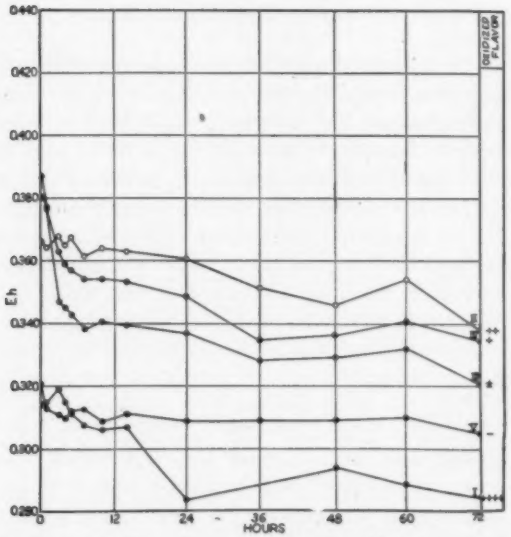


FIG. 3. The effect of different concentrations of added ferrous iron on the oxidation-reduction potentials of milk and the development of oxidized flavor.

I—50 parts per million of added ferrous iron.
II—25 parts per million of added ferrous iron.
III—10 parts per million of added ferrous iron.
IV— 5 parts per million of added ferrous iron.
V— 0 parts per million of added ferrous iron.

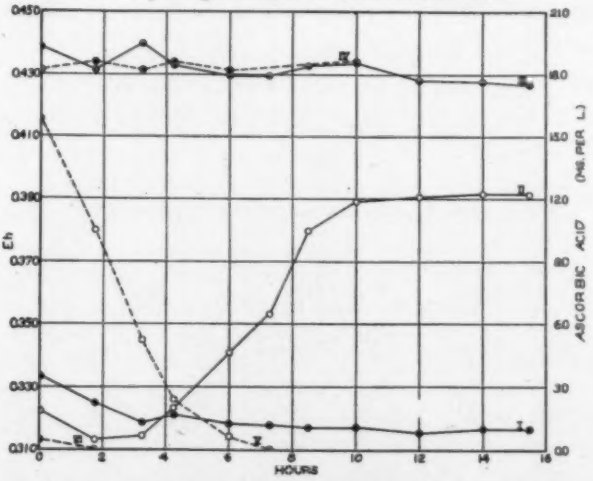


FIG. 4. The influence of time of copper contamination on the oxidation-reduction potentials of milk and the oxidation of the reduced ascorbic acid present in the milk.

I—Without added copper.
II—Copper (2 p.p.m.) added after pasteurization.
III—Copper (2 p.p.m.) added before pasteurization.
IV—Ascorbic acid content of I.
V—Ascorbic acid content of II.
VI—Ascorbic acid content of III.

tion of nearly all of the reduced ascorbic acid before the pasteurization process had been completed. In the sample of milk to which copper was added after pasteurization the reduced ascorbic acid was completely oxidized after 7 hours. During the same period of time there was no marked change in reduced ascorbic acid content of the milk to which no copper had been added. Figure 4 shows that the oxidation-reduction potential of pasteurized milk containing copper did not increase until nearly all of the reduced ascorbic acid had been oxidized. The O–R potential of the sample of milk to which copper had been added before pasteurization, had reached its maximum before the potential readings were started and continued to remain higher than the potential of the milk to which copper had been added after pasteurization.

Copper addition to whole milk, skimmilk and cream

Figure 5 summarizes the results of this experiment. Skimmilk and whole milk were found to have O–R potentials of about the same Eh values. The addition of two parts per million of copper caused practically identical increases in potential. The 29 per cent cream showed higher Eh values in the sample to which no copper had been added than did the whole milk and skimmilk. This was also true of the series in which copper was added. The skimmilk and whole milk developed the same intensity of oxidized flavor on the addition of copper, while the oxidized flavor was more intense in the case of the cream.

A study of milk from individual cows

The effect of adding copper to milk from individual cows is shown in figure 6, and it also shows the difference in potential of the normal milk

TABLE 2

A comparison of the effect of the addition of copper on the oxidation of the reduced ascorbic acid in the pasteurized milks of four individual cows

Time after adding copper	Ascorbic acid per liter							
	Cow #33		Cow #68		Cow #416		Cow #426	
	Cu 0 p.p.m.	Cu 2 p.p.m.	Cu 0 p.p.m.	Cu 2 p.p.m.	Cu 0 p.p.m.	Cu 2 p.p.m.	Cu 0 p.p.m.	Cu 2 p.p.m.
hrs.	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*
0.25	17.80	12.48	17.45	13.40	15.30	12.45	23.00	15.30
3	17.80	6.55	17.45	7.15	13.70	3.45	21.15	9.35
5	17.45	0.94	17.45	2.50	13.70	1.56	20.15	3.22
14.5	17.45	0	17.45	0	11.85	0	17.75	0
20								
26	16.20	0	14.65	0	10.00	0	16.20	0
37	16.20	0	13.10	0	8.42	0	14.35	0
45								
52	12.80	0	10.00	0	6.25	0	13.10	0
64	8.75	0	7.50	0			10.60	0
72	7.50	0	7.20	0	2.60	0	10.60	0

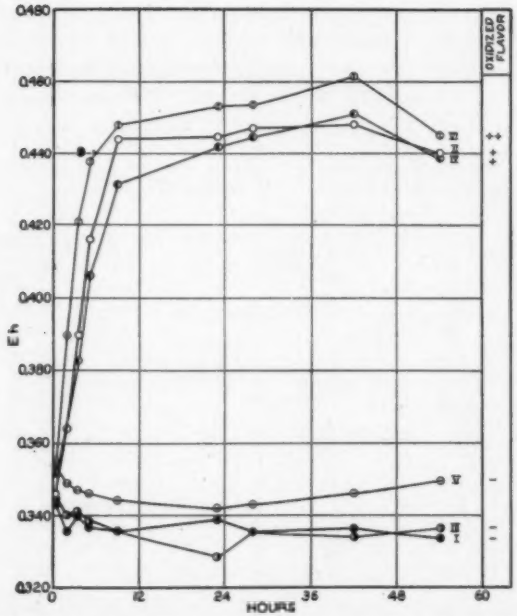


FIG. 5. A study of the influence of added copper on the oxidation-reduction potentials of whole milk, skimmilk and cream.

I—Whole milk, no added copper.
II—Whole milk with added copper (2 p.p.m.).
III—Skimmilk, no added copper.
IV—Skimmilk with added copper (2 p.p.m.).
V—29 per cent cream, no added copper.
VI—29 per cent cream with added copper (2 p.p.m.).

from individual cows. Table 2 gives the results of the reduced ascorbic acid determination on the same milks. Comparing the results in figure 6 with the results in table 2, the milk from cow #426 had the highest ascorbic acid content and the lowest oxidation-reduction potential in the normal milk. The addition of copper to this milk caused the smallest increase in potential and it did not develop oxidized flavor. The milk from cow #416 had the lowest reduced ascorbic acid content and highest oxidation-reduction potential in the normal milk. The milks from cows #33 and #68 had about the same ascorbic acid content and oxidation-reduction potential. The addition of copper caused about the same increase in potential and the same degree of oxidized flavor. The addition of copper to the milk from cow #416 caused the potential to raise to the same level as in the milks with added copper from cows #33 and #68, but the degree of oxidized flavor was less. Cows #33 and #68 were Holsteins and cows #416 and #426 were Guernseys.

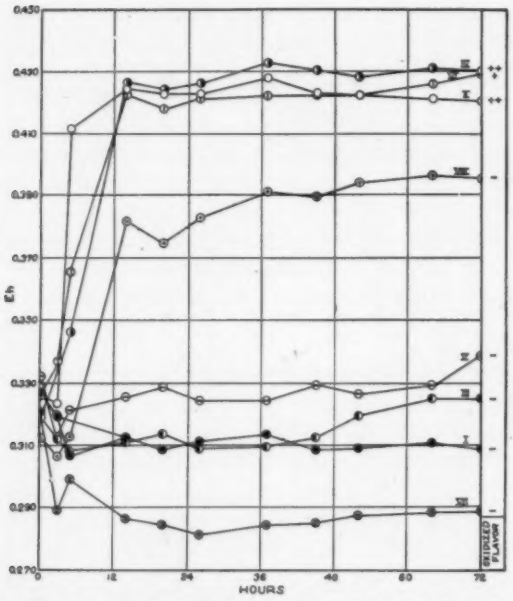


FIG. 6. The change in oxidation-reduction potentials and the development of oxidized flavor following the addition of copper to the pasteurized milks of four cows.

I—Milk from cow #33, no added copper.
II—Milk from cow #33 with added copper (2 p.p.m.).
III—Milk from cow #68, no added copper.
IV—Milk from cow #68 with added copper (2 p.p.m.).
V—Milk from cow #416, no added copper.
VI—Milk from cow #416 with added copper (2 p.p.m.).
VII—Milk from cow #426, no added copper.
VIII—Milk from cow #426 with added copper (2 p.p.m.).

Ascorbic acid as an anti-oxidant

The experimental results obtained from the study of ascorbic acid and d-isoascorbic acid as anti-oxidants are given in figure 7 and table 3. The addition of both forms of ascorbic acid caused a marked decrease in the oxidation-reduction potentials of the milks to which they were added. During the entire storage period the added ascorbic acids kept the potential down in the samples to which copper had been added, but the reduced ascorbic acid was being continually oxidized in these samples. At the end of the 54 hours of storage nearly all of the reduced ascorbic acid had been oxidized. More of the d-isoascorbic acid had been oxidized than had the ascorbic acid. During the period of the oxidation of the ascorbic acids, the potentials were lower in the samples containing copper than in the other samples. Although the milk containing d-isoascorbic acid and added cop-

per had the lowest Eh values during the entire storage period, it developed an oxidized flavor that was as intense as the flavor in the control sample to which copper had been added.

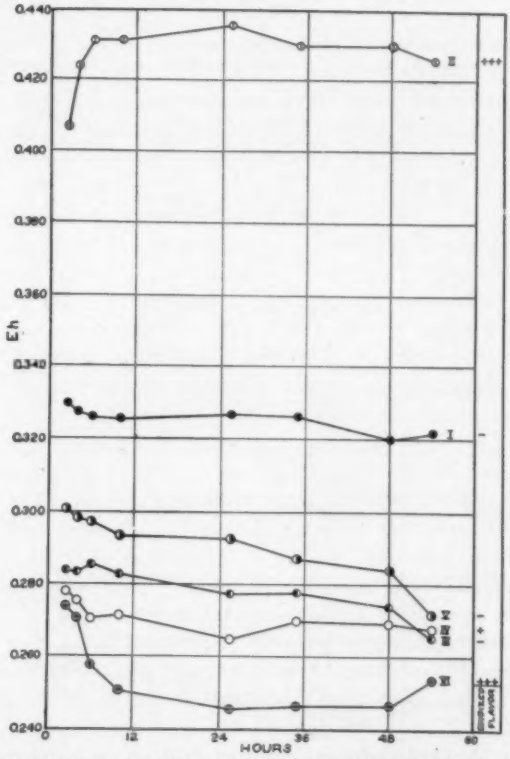


FIG. 7. The influence of added copper and ascorbic and d-isoascorbic acid on the oxidation-reduction potentials of milk and the development of oxidized flavor.

I—Without added ascorbic acid or copper.
II—Without added ascorbic acid, but with added copper (3 p.p.m.).
III—With added ascorbic acid (100 mg. per liter), but without added copper.
IV—With added ascorbic acid (100 mg. per liter) and copper (3 p.p.m.).
V—With added d-isoascorbic acid (100 mg. per liter) but without added copper.
VI—With added d-isoascorbic acid (100 mg. per liter) and copper (3 p.p.m.).

Change in oxidation-reduction potential caused by electrical current

By passing electrical current through milk it was possible to alter the oxidation-reduction potential. The greatest decrease in potential was effected by placing the negative electrode in the milk and the positive electrode in the sodium chloride solution contained in the porous cup. The curves plotted from the data obtained in this experiment are shown in

TABLE 3

The influence of added copper on the ascorbic acid content of normal milk and milk to which ascorbic acid and d-isoascorbic acid have been added

Time after adding copper	Ascorbic acid content					
	Without added ascorbic acid		With added ascorbic acid		With added d-isoascorbic acid	
	Without added copper	3 p.p.m. added copper	Without added copper	3 p.p.m. added copper	Without added copper	3 p.p.m. added copper
hrs.	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*	*mg.*
0.5	17.60	10.25	104.00	95.25	104.00	87.50
2.5	17.60	0	104.00	57.25	104.00	51.75
4						
6	17.60	0	104.00	51.60	103.50	43.00
10						
25.5	16.65	0	103.50	41.00	102.00	38.10
34.5	15.80	0	103.50	18.65	102.00	16.60
48						
54	15.80	0	96.25	12.95	96.00	7.90

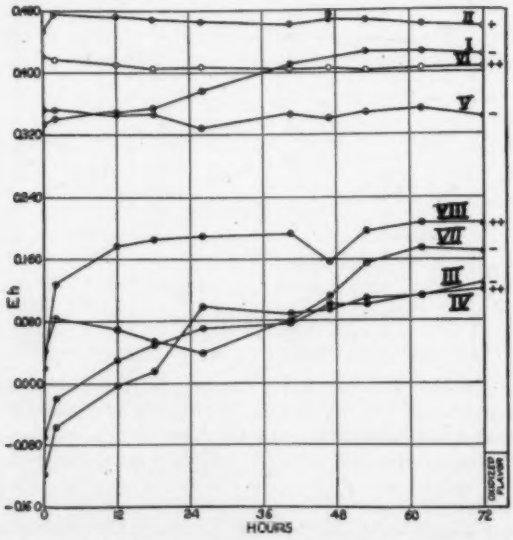


FIG. 8. The use of electrical currents as means of changing the oxidation-reduction potentials of milk and the influence on oxidized flavor development.

I—No electrical treatment, no added copper.
II—No electrical treatment, with added copper (2 p.p.m.).
III—Negative electrode in milk, no added copper.
IV—Negative electrode in milk, with added copper (2 p.p.m.).
V—Positive electrode in milk, no added copper.
VI—Positive electrode in milk, with added copper (2 p.p.m.).
VII—Both electrodes in milk, no added copper.
VIII—Both electrodes in milk, with added copper (2 p.p.m.).

figure 8. Though it was possible to decrease the potential, in no case did the treatment prevent the development of oxidized flavor when copper was added to the samples.

DISCUSSION

A number of investigators, Gebhardt and Sommer (5), Tracy, Ramsey and Ruehe (17), Thurston (15) and others, have shown that the addition of copper to milk causes an increase in the oxidation-reduction potential. Copper is known to be a very effective catalyst in causing the development of oxidized flavor. From these observations it is logical to assume that the development of oxidized flavor is due to or accompanied by an increase in the oxidation-reduction potential of the milk.

Copper was found to cause a sharp increase in the oxidation-reduction potential shortly after it was added to the milk. After the potential has reached its new level it continues to remain nearly constant during the remainder of the storage period. The length of time required for this sharp increase is dependent upon the concentration of added copper. In these experiments the addition of 2 and 5 p.p.m. of copper caused an immediate increase in potential, while with the lower concentrations there was a lag period.

It has been shown in figure 4 that the oxidation-reduction potential does not increase until the reduced ascorbic acid in the milk has nearly all been oxidized. These results are in keeping with the observations made by Turgeon, Stebnitz and Sommer on the Ritter's test as a means of determining copper contamination. These workers found that the vitamin C content of the milk was quite uniformly reduced to 7 milligrams per liter at the time of the first color change and reduced to zero by the time color was definitely developed. The conclusion may be drawn that the development of color in the Ritter's test is due to an increase in the O–R potential of the medium.

The addition of ferric iron to milk caused a gradual increase in the potential during the entire storage. The higher the concentration of added ferric iron, the greater was the resulting potential. The addition of 50 p.p.m. of ferric iron did not cause the potential to rise higher than the addition of 0.25 p.p.m. of copper. Only in the samples of milk where ferric iron had been added at concentrations of 25 and 50 p.p.m. was there any evidence of an oxidized flavor.

Ferrous iron caused a decrease in the oxidation-reduction potential when it was added to milk. Immediately upon its addition to milk the resulting potential was higher (except on the addition of 50 p.p.m.) than in the samples to which copper and ferric iron had been added, but on storage the oxidation-reduction potential kept decreasing. The sample of milk containing 50 p.p.m. of added ferrous iron developed a more intense oxidized flavor than did the sample of milk containing 5 p.p.m. of copper; yet there

was a difference of 0.135 in Eh. Concentrations of 25 and 50 p.p.m. of added ferrous iron to milk caused intense oxidized flavor, while the same concentrations of ferric iron caused only a questionable development of the off-flavor. The results were found to be the same with the use of pasteurized milk from an individual cow or with pasteurized mixed herd milk. In the case of the mixed herd milk the development of the oxidized flavor was more intense. From these findings it would seem that the development of oxidized flavor in milk is dependent upon the catalyzing properties of certain metallic ions and not on the change in potential which they may create.

The addition of copper to skimmilk and whole milk caused about an identical change in O–R potential. The cream had an original O–R potential higher than did the skimmilk and whole milk, and the resulting potential on the addition of copper was also higher. Since skimmilk had developed the same intensity of oxidized flavor as did the whole milk, this gives evidence to the fact that the phospholipids are the substances which undergo chemical change on the development of oxidized flavor. These findings are in agreement with the work of Thurston, Brown and Dustman (16) and Swanson and Sommer (14). The cream developed a more intense oxidized flavor than the whole milk, which is in agreement with the findings of Roland and Trebler (12).

The normal pasteurized milks from individual cows vary in their oxidation-reduction potentials. In comparing the milk from four individual cows, there was a relation between the reduced ascorbic acid content of the milk and its oxidation-reduction potential. Milk from the cow having the lowest ascorbic acid content had the highest O–R potential of the four milks. The milk having the highest reduced ascorbic acid content had the lowest O–R potential, and the milks from the other two cows had about the same reduced ascorbic acid content and O–R potential. There was no correlation found between breed and reduced ascorbic acid content as the high and low milks were from Guernseys and the other two from Holsteins. The milk with the highest reduced ascorbic acid content showed less increase in O–R potential on addition of copper and did not develop an oxidized flavor.

The addition of crystalline ascorbic acid and crystalline d-isoascorbic acid to milk was found to cause a marked decrease in the oxidation-reduction potential. The addition of copper to milks containing these two forms of ascorbic acid caused oxidation of the ascorbic acid but during the entire period the O–R potential was lower than in the samples which contained added ascorbic acid but no added copper. As the oxidation of the ascorbic acid is taking place, the potential is lower than where there is no rapid oxidation of the reduced ascorbic acid. The addition of 100 mg. per liter crystalline ascorbic acid to milk inhibited but did not completely prevent the development of oxidized flavor. Though d-isoascorbic acid produced

the lowest O–R potential readings, it did not prevent the development of oxidized flavor.

Passing electricity through milk has been used in Central Europe as a means of neutralizing developed acidity in milk and cream. This same principle was used as a means of changing the O–R potential in milk. By means of passing electricity through milk it was possible to lower the O–R potential of milk considerably, but such changes in potential were found to exhibit no inhibiting effects on the development of oxidized flavor.

SUMMARY AND CONCLUSIONS

The relation of oxidation-reduction potential measurements to the development of oxidized flavor in milk was studied to determine if there was any relation between an increase in O–R potential and the development of oxidized flavor in milk.

Copper was capable of producing approximately the same intensity of oxidized flavor when added at one-tenth of the concentration at which ferrous iron was added to milk. Shortly after the addition of copper to milk there was a rapid increase in oxidation-reduction potential, while ferrous iron caused the oxidation-reduction potential to decrease. Ferric iron when added to milk caused the O–R potential to increase slowly during the storage period but produced little or no oxidized flavor.

When copper was added to milk, the oxidation-reduction potential did not increase until practically all of the reduced ascorbic acid was oxidized.

The addition of copper to whole milk, skimmilk and cream was followed by a marked increase in O–R potential. The cream developed a more intense oxidized flavor than the whole milk and skimmilk.

The oxidation-reduction potential of milk from individual cows was found to vary; as the reduced ascorbic acid content of milk from individual cows increased, the O–R potential decreased.

Crystalline ascorbic acid and crystalline d-isoascorbic acid when added to milk lowered the oxidation-reduction potential. Ascorbic acid had an inhibiting effect on the development of oxidized flavor, but even at the low Eh reading produced by the addition of d-isoascorbic acid, the milk developed oxidized flavor when copper was added.

By passing electrical current through milk, it was possible to lower the oxidation-reduction potential, but the resulting lowered O–R potential did not inhibit the development of oxidized flavor.

From these studies on oxidation-reduction potentials in relation to the development of oxidized flavor, the Eh value of the medium does not seem to inhibit or accelerate the development of the off-flavor.

REFERENCES

(1) Brown, W. C., Dustman, R. B., and Thurston, L. M. Oxidized flavor in milk. V. The effect of metal-developed oxidized flavor on the iodine number of the milk fat. J. Dairy Sc., 20: 599–604. 1937.

(2) BROWN, W. C., THURSTON, L. M., AND DUSTMAN, R. B. Oxidized flavor in milk. III. Time of copper contamination during production and processing, and aeration versus no aeration as related to oxidized flavor development. J. DAIRY SC., 19: 753–760. 1936.

(3) CHILSON, W. H. What causes most common off-flavors of market milk. Milk Plant Monthly, 24: 11, 24–28; 12, 30–34. 1935.

(4) DAHLE, C. D., AND PALMER, R. S. The oxidized flavor in milk from the individual cow. Pa. Agr. Exp. Sta. Bull. 347. 1937.

(5) GEBHARDT, H. T., AND SOMMER, H. H. The solubility of metals in milk. I. The solubility of copper under various conditions. J. DAIRY SC., 14: 416–446. 1931.

(6) GRATZ, O. La désacidification du lait et de la créme par voie électrique. Le Lait, 14: 145–154. 1934.

(7) GREENBANK, G. R. Control of oxidized flavor in milk. Proc. Intern. Ass'n Milk Dealers, Lab. Sect., 29th Ann. Convention, pp. 101–116. 1936.

(8) JOHNSON, M. J. (Biochemist, U. of Wis.) Interview, February, 1938.

(9) KON, S. K., AND WATSON, M. B. Effect of light on the vitamin C of milk. Biochem. J., 30: 2273–2290. 1936.

(10) MORRIS, A. J., AND SOMMER, H. H. Minerals and acidity injure quality of cream in storage. Ann. Report Wis. Agr. Exp. Sta., pp. 132–133. 1932.

(11) PIEN, J., AND BAISSE, J. La théorie de la désacidification électrique du lait. Le Lait, 16: 921–941. 1936.

(12) ROLAND, C. T., AND TREBLER, H. A. The effect of fat content on oxidized flavor in milk and cream. J. DAIRY SC., 20: 345–350. 1937.

(13) SHARP, P. F., TROUT, G. M., AND GUTHRIE, E. S. Vitamin C, copper and the oxidized flavor of milk. Milk Plant Monthly, 26: 5, 32–34, 44. 1937.

(14) SWANSON, A. M., AND SOMMER, H. H. Oxidized flavor in milk. I. Effect of the development of oxidized flavor on the iodine number of the phospholipid fraction of milk. J. DAIRY SC., 23: 3, 201–208. 1940.

(15) THURSTON, L. M. Oxidized flavor in milk. Proc. Intern. Ass'n Milk Dealers, Lab. Sect., 28th Ann. Convention, pp. 121–141. 1935.

(16) THURSTON, L. M., BROWN, W. C., AND DUSTMAN, R. B. Oxidized flavor in milk. I. The probable relation of lecithin to oxidized flavor. J. DAIRY SC., 18: 301–306. 1935.

(17) TRACY, P. H., RAMSEY, R. J., AND RUEHE, H. A. Certain biological factors related to tallowiness in milk and cream. Ill. Agr. Exp. Sta. Bull. 389. 1933.

(18) TROUT, G. M., AND SHARP, P. F. The reliability of flavor judgments, with special reference to the oxidized flavor of milk. N. Y. (Cornell) Agr. Exp. Sta. Memoir 204. 1937.

(19) TURGEON, J. P., STEBNITZ, V. C., AND SOMMER, H. H. Vitamin C retards development of oxidized flavor in milk and complicates test for copper. Ann. Report Wis. Agr. Exp. Sta., pp. 63–64. 1937.

(20) VELLINGER, P. E. Le potentiel de l'electrode au calomel saturee entre 0° to 40°. Arch. Phys. Biol., 5: 119–124. 1926–27.

(21) WEBB, R. E., AND HILEMAN, J. L. The relation of the oxidation-reduction potential of milk to oxidized flavor. J. DAIRY SC., 20: 47–57. 1937.

(22) WINKLER, W. Das Electro-Entsauerungsverfahren der "Elact" Gesellschaft für elektrische Apparate. Österr. Milchw. Ztg., 40: 253–256. 1933.

(23) WOLJAGIN, A., AND SCHEIMPFLUG, W. Entsäuerung von Milch mit Hilfe der Electrodialyse. Österr. Milchw. Ztg., 43: 200–201. 1936.

A COMPARATIVE EVALUATION OF AN ICE CREAM SUPPLY AS IT REACHES THE CONSUMER*

L. K. CROWE AND P. A. DOWNS
Dairy Husbandry Department, University of Nebraska

The prospective ice cream consumer is often confronted with a multiplicity of prices for the usual consumer-size package of ice cream. The problem is no less complex after the seller has been questioned as to the reasons for the price differences.

In an effort to gain some direct information bearing on this problem, vanilla ice cream was purchased in pint quantities in a typical consumer manner, that is, without indication to the dispenser as to the use that was to be made of the ice cream. These samples were brought immediately to the laboratory and the gross weight obtained. Portions were withdrawn with a sterile spatula for bacterial analysis and at the same time an organoleptic examination was made. The remainder of the contents of the package was transferred to a screw-top pint jar and the container was weighed to obtain the net weight of the ice cream. The ice cream was melted at room temperature and, when necessary in removing incorporated air, warmed to 90 degrees Fahrenheit. The overrun was calculated by the use of the specific gravity as determined with a 100-milliliter pycnometer bottle and a torsion balance. Total solids and fat were determined by the Mojonnier procedure and protein by the Gunning method using a 5-gram sample. The pH was determined electrometrically with a quinhydrone electrode. The total bacterial count was made by the standard plate method on a volumetric basis. The number of organisms of the coli group was obtained by the plate method using violet red bile agar, and in the case of low count samples this was supplemented by the brilliant green lactose bile broth method. The samples are designated in table 1 according to number with the suffix P or B indicating factory-filled packages or fountain-dipped bulk ice cream, respectively.

RESULTS AND DISCUSSION

Inspection of the data in table 1 will show that the price of pint samples of vanilla ice cream as available to the consumer in the market studied, ranged from fifteen to thirty cents with intermediate prices of seventeen, twenty, and twenty-five cents. The net weight of these pint samples averaged 298.0 grams with a range of 212 grams to 465 grams. The heaviest sample was a fountain-dipped sample in the highest price level, while the lowest weight sample was a factory-filled pint in the lowest price level. This weight-price

Received for publication December 4, 1939.

* Published with the approval of the Director as Paper No. 254, Journal Series, Nebraska Agricultural Experiment Staion.

TABLE 1

Composition and characteristics of pint samples of vanilla ice cream as purchased by the consumer

Plant	Sample	Pint price	Net wt.	Over-run calc.	Total solids	Butter fat	Protein N×6.38	pH	Bacteria per ml.		Flavor		Body	
									Total	Coli V.R.A.	Score	Criticism*	Score	Criticism**
		¢	*gms.*	%	%	%	%		*thous.*					
A	1–P	20	262	96.4	39.45	14.25	4.56	6.40	5.2	−10	44.0	.....	23.0	.....
A	6–P	15	223	129.3	38.42	12.97	3.97	6.37	26.9	120	41.0	Un.	22.0	Fl.
A	8–B	20	410	24.7	38.37	12.30	4.77	6.40	126.0	3450	43.0	L.F.F.	23.0	H.
B	2–B	25	401	28.2	39.24	14.18	4.13	6.35	19.0	−10	42.0	O.I.	23.5	H.
B	3–P	15	245	106.5	39.36	13.45	4.49	6.32	3.6	200	43.0	L.F.F.	23.0	Fl.
B	4–P	20	273	86.6	38.89	15.23	4.36	6.35	7.9	−10	44.5	.....	23.0	.....
B	7–P	20	241	111.5	37.26	14.21	4.23	6.38	18.0	0	44.0	.....	23.0	.....
C	12–P	20	264	92.6	40.55	13.63	4.33	6.39	2.0	−10	41.0	Ox.P.	22.0	Icy
C	13–P	15	241	112.5	39.08	12.29	4.63	6.33	7.6	30	42.0	L.F.F.	22.0	Icy
D	23–B	25	335	53.2	38.17	13.69	4.19	6.64	4.4	−10	42.0	Ca.	23.5	.....
D	24–P	15	222	128.6	37.38	13.27	4.40	6.76	13.7	0	43.0	Ca.	22.5	Sl.Icy
D	25–P	20	275	85.9	37.63	13.59	4.32	6.43	17.2	0	42.0	Ca.	23.5	.....
E	5–P	20	262	93.5	38.22	12.32	3.96	6.38	10.5	0	43.0	L.F.F.	22.5	Sl.Icy
F	9–P	20	303	69.2	39.04	13.93	4.03	6.39	30.0	−10	44.5	.....	22.5	Sl.Icy
G	10–P	20	270	89.5	37.85	13.45	4.57	6.42	1.1	270	40.0	V.Un.	21.0	IcyFl.
H	11–P	17	305	68.4	39.56	13.70	4.41	6.40	3.2	−10	42.0	Un.	22.5	Sl.Icy
I	14–P	15	212	141.1	39.61	12.16	4.13	6.35	8.8	190	41.0	Un.	21.0	Icy
J	15–P	15	318	61.9	39.16	13.73	4.00	6.39	0.5	0	43.5	T.S.	22.5	Icy
K	16–P	20	304	68.2	40.19	16.97	3.66	6.37	51.2	−10	38.0	Cy.O.I.	22.0	H.
L	17–P	15	244	108.7	37.46	13.92	4.52	6.56	9.5	60	38.5	O.I.Un.	22.5	Icy
M	18–P	15	264	94.3	38.25	14.00	4.08	6.40	1.7	0	39.0	Un.	22.5	Icy
N	19–P	20	228	125.3	39.35	13.57	4.10	6.41	1.0	0	41.0	Un.	22.0	Icy
O	20–P	20	231	119.1	38.51	13.66	4.08	6.74	2.4	0	42.0	L.F.	22.0	IcyFl.
P	21–P	20	413	24.2	38.99	13.47	4.02	6.40	0.3	−10	43.5	.....	22.5	H.
Q	22–P	15	225	125.1	38.85	15.31	4.10	6.40	19.2	20	44.0	.....	22.5	Fl.

TABLE 1—(*Continued*)

Plant	Sample	Pint price	Net wt.	Over-run calc.	Total solids	Butter fat	Protein N×6.38	pH	Bacteria per ml.		Flavor		Body	
									Total	Coli V.R.A.	Score	Criticism*	Score	Criticism**
		¢	*gms.*	%	%	%	%		*thous.*					
R	26–P	20	287	79.1	38.67	13.35	4.16	6.38	5.2	0	42.0	.....	23.5	.....
B	27–B	30	465	9.8	38.34	13.23	4.16	6.38	77.0	−10	43.5	Sl.C.Ck.	24.0	H.
B	29–B	15	403	25.9	38.97	13.68	4.20	6.43	1540.0	750	43.5	Sl.C.Ck.	24.0	Sl.H.
B	30–B	25	460	11.2	38.45	13.24	4.21	6.37	125.0	30	44.0	L.F.F.	23.5	Cr.
B	32–B	25	295	73.7	39.84	13.52	4.24	6.35	43.0	−10	43.5	Sl.C.Ck.	24.0	Sl.H.
B	37–B	20	360	42.6	39.17	14.32	4.20	6.43	29.0	−10	43.5	Sl.C.Ck.	23.5	Icy
A	31–B	25	339	50.8	37.21	13.54	4.38	6.43	26.0	−10	44.0	L.S.	23.5	Icy
A	33–B	25	409	24.9	37.42	13.61	4.28	6.39	3.5	−10	44.0	L.S.	24.0	Sl.H.
D	35–B	20	330	53.4	38.23	13.34	4.20	6.65	32.0	450	44.5	L.F.F.	23.5	Sl.Fl.Cr.
O	36–P	20	219	131.3	38.48	13.88	4.46	6.41	4.5	50	40.0	Un.	23.0	Fl.Cr.
Q	34–P	15	246	109.2	38.30	12.94	4.31	6.40	34.0	30	44.5	L.F.F.	23.5	Fl.
S	28–P	15	251	104.3	37.86	13.10	4.13	6.45	120.0	10	42.5	C. or P.	22.5	IcyCr.
Average all samples		19.4	298.0	80.0	38.64	13.65	4.24	6.43			42.5		22.8	
Average 15¢ samples			257.8	104.0	38.56	13.40	4.25	6.43			42.1		22.5	
Average 20¢ samples			290.1	81.9	38.76	13.85	4.24	6.43			42.4		22.7	
Average 25¢ samples			373.2	40.3	38.39	13.63	4.24	6.42			43.3		23.7	

* Flavor criticism key:
Un.—Unnatural.
V.—Very.
L.F.—Lacks flavor.
L.F.F.—Lacks fine flavor.
O.I.—Old ingredient.
P.—Powder.
Ox.P.—Oxidized powder.
C.—Condensed.
Sl.—Slight.
Ca.—Caramel.
Ck.—Cooked.
Cy.—Cowy.
T.S.—Too sweet.
L.S.—Lacks sweetness.

** Body criticism key:
Fl.—Fluffy.
H.—Heavy.
Icy—Icy.
Sl.—Slight.
Cr.—Coarse.

relationship was found on the average for all samples; that is, the average weight was higher for each increase in price level. When converted to a basis of the net weight of ice cream purchased for a certain price, that is, twenty cents, we find the advantage to the consumer decidedly in favor of the ice cream selling at the lowest price level, with the twenty and twenty-five cent pints about equal, but with a slight advantage (8.4 grams) for the higher priced pints.

The per cent overrun as calculated includes the extremes of 9.8 and 141.1 with an average of 80.0. The minimum overrun for all samples was found in the fountain-dipped package group; the maximum for this group was 73.7 per cent. The maximum overrun for all samples occurred in the factory-filled package group, while the minimum overrun for this group is 24.2 per cent. The highest overrun occurs in the lowest price level group with a minimum overrun for this group of 25.9 per cent.

In a somewhat similar comparison of ice cream purchased in metropolitan Chicago, Grumbine and Halliday (1) found a range in weight of pint samples from 248.8 grams to 480.2 grams and the overrun to include the extremes of 14.1 per cent and 143.0 per cent.

If 6.4 to 6.6 is accepted as the normal pH of ice cream mix made from fresh ingredients as proposed by Sommer (2), we may assume two of the samples obtained were made from slightly neutralized mix.

A study of the total solids content of these samples showed a range from 37.21 per cent to 40.19 per cent with no significant difference in this characteristic between bulk and factory-filled packages. The butterfat content varied from 12.16 per cent to 16.97 per cent with both of these extremes occurring in the factory-filled package group. On the average there was a slightly higher percentage of butterfat in the factory-filled pints and in the higher-price-range pints. In making this comparison it should be borne in mind that the state law (3) specifies at least 14 per cent of butterfat for vanilla ice cream, with this exception: "There shall be allowed a tolerance of one-half per cent, provided the one-half per cent is not constantly below the standard." The percentage of samples containing less than the legal percentage of fat was relatively uniform for all groups of samples; this was 78.4 per cent for all samples, 81.8 per cent and 80.8 per cent respectively for bulk and package samples, and 70.6 per cent for the twenty-cent-pint group. On the basis of the 13.5 per cent tolerance, 37.8 per cent of all samples failed to comply as did 36.4 per cent and 42.3 per cent, respectively, of the bulk and package samples and 35.3 per cent of the twenty-cent-pint group.

In making a comparison of these samples on the basis of calculated calorific value received for an expenditure of twenty cents (table 2), the average for all samples was 696.2 but with the wide range of 489.2 to 1205.1. The bulk samples showed the widest variation in this respect of any group, while the lowest price group was second in variation.

In examination of the results of bacterial analysis of these samples, the total count of six samples was above 50,000; four of these were fountain-dipped packages and two factory filled. In the less-than-10,000-total-count group there were eighteen samples; two of these were fountain-dipped pints and sixteen factory-filled pints. The three samples with the highest total count were all fountain-dipped pints, one at 1½ million and the other two at approximately 125 thousand. Only one factory-filled pint occurred in the group with a total count of more than 100,000.

TABLE 2

Quantities purchased for twenty cents

	Total solids	Butter-fat	Protein (N × 6.38)	Carbohy-drates (calculated)	Calories (calculated)
	gms.	*gms.*	*gms.*	*gms.*	
All samples (average)	120.3	42.4	13.2	65.4	696.2
15-cent samples (average)	132.4	46.0	12.8	71.1	761.6
20-cent samples (average)	112.5	40.1	12.3	61.7	656.6
25-cent samples (average)	114.5	40.6	12.6	61.2	660.7
Factory-filled pints (average)	115.8	41.0	11.8	62.2	668.2
Fountain-dipped pints (average)	130.9	42.8	14.5	73.0	762.6

The three samples with the highest coli count were in the fountain-filled group, one in the lowest price level and two in the twenty-cent-pint group. Two of these three samples, one of which was in the lowest price level, were highest and second highest of all samples in total count. The sample containing the third highest number of coli showed a total count of 32,000. In the four cases of factory-filled packages in the less-than-10,000-total-count group the number of coli was 270, 200, 190, and 50 per milliliter, indicating that the coli content of these samples did not originate with the dispenser.

The flavor and body scores of the samples in the fifteen- and twenty-cent-pint groups show no significant difference. The twenty-five cent pints and the fountain-filled pints averaged approximately one point higher in body score and in flavor score than the average for all samples.

When the results of the analyses made were computed to the basis of product received for a definite expenditure (table 2), the advantage was with the lowest-priced group in all comparisons made where different price level groups were the basis for the comparison. In a similar comparison it was indicated that the purchaser of the fountain-dipped package receives an advantage as compared to the purchaser of the factory-filled package when these two groups are the basis for comparison.

CONCLUSIONS

This preliminary study of a limited number of pint samples of vanilla ice cream at all price levels available to the consumer in the trade territory

studied does not indicate the reason for the difference in price level when a comparison is made on the basis of the following: net weight of ice cream obtained; calculated overrun in per cent; composition including butterfat, total solids, protein and calculated carbohydrate; bacteria count of either total or colon type organisms; calorific value purchased for a certain expenditure, or quality as determined by organoleptic examination.

It is recognized that this is not an all-inclusive study of a problem of this character but it is believed that studies such as this carried out in a market at intervals of six months or one year would tend to bring to the consumer a more uniform product and tend to aid in establishing a sound basis for differences in price per unit quantity of ice cream purchased.

REFERENCES

(1) Grumbine, Cecily Ruth, and Halliday, Evelyn G. Chemical and bacteriological studies on ice cream. Food Research, 3: 6, 653. 1938.

(2) Sommer, H. H. Physical and bacteriological tests on commercial ice cream samples. Ice Cream Review 20: 6, 38. 1937.

(3) State of Nebraska, Department of Agriculture, Pure Food Law Bulletin No. 4.

THE VALUE OF SODIUM METAPHOSPHATE IN DETERGENT MIXTURES IN THE CLEANING OF MILKING MACHINES*

W. L. MALLMANN AND C. S. BRYAN
Section of Bacteriology, Michigan Agricultural Experiment Station
AND
L. H. BEGEMAN
Lansing Department of Health

The process of cleaning the milking machine has claimed the attention of the dairy sanitarians ever since the advent of this device. Although numerous publications have appeared from time to time recommending various methods of cleaning and sterilizing, and although these methods can be applied with considerable success, the fact remains that milking machines are still serious foci of contamination in market milk. The mechanical structure of the machine, even though marked simplications have been affected, makes the cleaning and disinfecting procedure difficult when compared to the equipment necessary for hand milking. This does not mean that the equipment is really difficult to clean, but it does mean that the method of care is different and peculiar to this equipment. The milking machine is such a valuable adjunct to the dairy farm that the more or less insanitary conditions of these machines that prevails should be rectified by better methods of cleaning so that their use will not be discredited.

Not only may the dirty milking machines be an important source of bacterial contamination, but they may also be a reservoir of heat-resistant bacteria, which are responsible for the high count occasionally obtained in properly pasteurized milk. The role of milking machines as a source of heat-resistant bacteria is not unknown to the dairy sanitarian. Many times the dairy plants are accused of insanitary conditions or carelessness when most of the trouble lies with the producers who have been careless in the handling of their milking machines.

EXPERIMENTAL

In the spring of 1938, a large dairy in Michigan was having considerable trouble with high counts in its pasteurized milk. On several occasions samples were collected on three different routes from producers using milking machines. These machines had received little attention from the milk inspector so they represented conditions which may prevail under lax inspection. The producer samples were tested by the standard plating procedure. Each sample was then pasteurized and another plating made to

Received for publication December 14, 1939.

* This study was made possible through a grant from Calgon, Inc., of Pittsburgh, Pennsylvania. Journal Article No. 363 n.s. from the Michigan Agricultural Experiment Station.

determine the reduction affected by this heating. The data are presented in table 1. The data show that a large percentage of the bacteria in these milks were resistant to pasteurization temperatures. Not only were the counts of raw milk high, but the percentage of reduction in count by pasteurization was unsatisfactory. Only 6 out of 23 samples showed reductions of 95 to 100 per cent. The picture presented by the bacteria counts of these producer samples is not unknown where inspections are lax.

TABLE 1

Bacteria counts of samples from producers using milking machines where field inspection was inadequate

Sample No.	Bacteria count of milk		Per cent reduction
	Raw	Pasteurized	
1	40,000	26,000	35.0
2	2,900,000	550,000	81.0
3	39,000	25,000	35.9
4	87,000	32,000	63.2
5	32,000	40,000	0.0
6	70,000	17,000	75.7
7	3,250,000	470,000	85.5
8	3,900,000	1,120,000	71.3
9	96,000	97,000	0.0
10	121,000	65,000	46.6
11	1,400,000	166,000	88.1
12	172,000	5,000	97.2
13	4,300,000	274,000	93.6
14	80,000	20,000	75.0
15	940,000	26,000	97.1
16	380,000	10,000	97.4
17	625,000	21,000	96.7
18	345,000	195,000	46.7
19	1,200,000	82,000	93.2
20	175,000	90,000	48.6
21	550,000	18,000	96.7
22	760,000	13,000	98.3
23	2,100,000	131,000	93.8
Average	1,024,000	152,000	
Geom. mean	374,000	21,000	94.3

At the same time that the above-mentioned samples were collected, examination was made of producer routes under inspection by a city dairy inspector and a field man employed by the dairy. Samples were collected from producers using milking machines. The samples were handled in exactly the same manner as before. The results are presented in table 2. The results show that the bacteria counts were reduced from 95 to 100 per cent in 9 out of 16 samples tested. With the exception of two producers, Nos. 2 and 6, there was little evidence of heat-resistant organisms. The two samples cited showed the presence of heat-resistant bacteria as indicated by the high pasteurized milk counts of 19,000 and 58,000 per ml., respectively.

TABLE 2

Bacteria counts of samples from producers using milking machines where field inspection was adequate

Sample No.	Bacteria count of milk		Per cent reduction
	Raw	Pasteurized	
1	34,000	1,000	97.1
2	285,000	19,000	93.3
3	4,000	100	97.5
4	17,000	500	97.1
5	82,000	7,000	91.5
6	630,000	58,000	90.8
7	655,000	2,000	99.7
8	17,000	350	97.9
9	170,000	6,000	96.5
10	6,500,000	2,000	99.9
11	38,000	4,000	89.5
12	40,000	7,000	82.5
13	75,000	9,000	88.0
14	35,000	9,000	74.3
15	190,000	3,000	98.4
16	575,000	400	99.9
Average	584,000	8,000	
Geom. mean	104,000	2,700	97.4

The results of these two series of tests, which are representative of others, made on these milk routes indicate that either the methods of cleaning or disinfecting the machines were faulty, or the performance of the same was not carried out successfully. From observations by the inspectors criticisms might be made rightfully that both methods and the application of the same were improper. The tests show that regular inspection is necessary and that even then milking machines may still produce an unsatisfactory supply of milk for pasteurization.

There is a dearth of information on methods of cleaning milking machines. Most publications place emphasis on the sanitation. The most common practice in cleaning consists of flushing machines with cold water after each milking and then placing the tubes on the racks for either alkali or chlorine treatment. Under these conditions machines are washed once a week with hot water and a detergent. This procedure is very poor operating practice.

A satisfactory method of cleaning consists in flushing with cold water immediately after milking, then with warm water and a detergent, and then placing the tubes on the racks for disinfection. This procedure does produce satisfactory results, but unfortunately this method is seldom practiced and even where it is used the method is not carried out with sufficient thoroughness to render the equipment free of milk wastes and lime deposits.

In the routine examination of milking machines, considerable accumulations of calcium phosphate or milkstone in the rubber tubing and the inner surfaces of the milking machines have been found irrespective of the

methods of cleaning, where the procedure was not thorough. These accumulations, as pointed out in the literature, are produced largely by the improper removal of the milk film, but the deposits of lime from the use of calcium hypochlorite and the salts from hard waters also play an important role.

The presence of milkstone is generally accepted as an indication of improper cleaning. Machines showing the presence of this substance are considered as insanitary, but in spite of continuous and frequent inspection it is commonly found.

It is the experience of the senior author that no chemical disinfection on the market today will function when the surface to be disinfected is covered with deposits such as occur in the rubber tubing of the milking machine. Neither lye nor chlorine has any penetrating power, as demonstrated by Mallmann and Chandler (1). They show the need of cleanliness as a necessary preliminary to disinfection. No disinfection can act economically or efficiently in the presence of excessive amounts of suspended materials or film providing the bacteria are embedded.

The problem of producing a better quality milk with milking machines appears to lie not in the development of a better sanitizer but in the development of better means of cleaning applicable to farm use and practice. It would seem that in addition to obtaining better disinfection by presenting a clean surface to the disinfectant, the proper cleaning of equipment would present clean surfaces to which the bacteria could not remain attached.

No data are available on milking machines to demonstrate the comparative effects of clean surfaces as compared to milkstone-covered surfaces in producing a low count milk. Accordingly, tests were made to measure the value of clean milking machine equipment in reducing bacteria counts. Arrangements were made with a local dairy to conduct tests in cooperation with some of their producers who were using milking machines. The samples were collected for a period of two weeks prior to cleaning the machines to obtain approximately average conditions with machines receiving the usual cleaning. After the collecting of these samples all the machines were carefully cleaned by the inspectors to be sure that they were free from milkstone. No change was made in the method of cleaning employed by the producer. Samples were collected for a period of three weeks following the cleaning of the machines by the inspectors. The results are given in table 3. It will be observed that a marked fall occurred in the geometrical count after cleaning. This reduction persisted for the entire period of three weeks for which the tests on the cleaned equipment were made.

In compiling the data before and after cleaning, two variables, cleaning and temperature, must be considered. The influence of temperature can

TABLE 3

The effect of cleaning milking machines on the bacteria count of the milk

Time of collection	Geometrical mean		
	No. of samples	Plate count	Microscopic clump count
Before cleaning	37	490,000	165,000
After cleaning	78	231,000	99,000

be eliminated by the fact that warmer weather occurred after cleaning, as the tests were started in late April and were discontinued early in June. As a matter of fact, if the temperature before and after cleaning had been constant the reduction would have been more pronounced than that reported. Thus, the reduction in bacteria count of the milk from the cleaned machines is due to the cleanliness of the machines themselves.

The use of tri-sodium phosphate, sodium metasilicate, and lye under certain conditions causes a formation of calcium phosphate or milkstone. This formation acted as a protective layer to the bacteria against chemical disinfection and also as a reservoir for the growth of bacteria. As demonstrated earlier in this paper, unclean machines are frequently sources of heat-resistant bacteria. If the formation of milkstone could be prevented it would be possible to produce low count milk with a minimum of heat-resistant bacteria. Schwartz and Gilmore (2) demonstrate that the addition of sodium metaphosphate to a detergent mixture used for mechanical dishwashing produced better results and eliminated the deposition of scale on the surface of the dishes and the equipment. Gilmore (3) states, "Sodium metaphosphate, although not a detergent, by forming soluble complex ions with the ions of calcium and magnesium in alkaline solutions, prevents completely the formation of insoluble alkaline salts and soaps that constitute the deposit formed in ordinary processed water."

To determine the value of sodium metaphosphate as a means of preventing the formation of milkstone, two sets of milking machines were tested in parallel. One set was flushed daily with a detergent mixture containing 20 per cent sodium metaphosphate, and the other set was cleaned in the same manner as the producer had used prior to the test. Both sets of machines were carefully cleaned at the start of the experiment. Samples were collected from each producer from time to time over a period of three weeks. The data for these experiments are presented in table 4. The data show that reductions in bacteria count result whether a sodium metaphosphate detergent mixture or other means of cleaning was employed. The data do not show that the sodium metaphosphate detergent mixture has any advantage from the standpoint of bacteria reduction over other methods of cleaning during a period of three weeks following a thorough cleaning of all of the machines.

The fact that all of the machines were cleaned at the start of the experiment and the producers were made aware of the fact that their cleaning

TABLE 4

The effect of cleaning milking machines with a detergent mixture containing sodium metaphosphate

Time of collection	Duration of tests	Geometrical mean		
		No. of samples	Plate count	Microscopic clump count
Sodium metaphosphate used				
Before cleaning	2 wks.	41	193,000	364,000
After cleaning	3 wks.	71	172,000	25,000
No sodium metaphosphate used				
Before cleaning	2 wks.	37	490,000	165,000
After cleaning	3 wks.	78	231,000	99,000

operations were unsatisfactory would likely cause them to be more careful. As a result, during the three weeks period of the tests both groups kept their machines in a clean condition, in spite of rather than because of, the type of cleaner used. It was quite evident that the amount of accumulation in the tubes would be slight in three weeks, and a longer period would be necessary to demonstrate the difference between a clean machine and one containing milkstone deposits.

The experiments were accordingly continued over a longer period of time. At the end of five and eleven months the monthly routine samples were checked for each group. These results are presented in table 5. It will be observed that the geometrical mean microscopic count showed a marked reduction in number of bacteria in favor of the sodium metaphosphate detergent mixture at the end of both five and eleven months periods. These experiments show that the introduction of sodium metaphosphate into the detergent mixture tends to keep the bacteria count at a relatively lower level than the cleaners used which lack this material.

An examination of the physical appearance of the milking machines showed a very marked difference between the machines cleaned with the sodium metaphosphate detergent mixture and those cleaned with other

TABLE 5

The effect of cleaning milking machines with a detergent containing sodium metaphosphate

Detergent contained	No. of producers	Duration of test	Geometrical mean
			Microscopic clump count
Sodium metaphosphate	7	5 months	110,000
No sodium metaphosphate	7	5 months	219,000
Sodium metaphosphate	7	11 months	77,000
No sodium metaphosphate	7	11 months	113,000

cleaners. The machines were examined nine months after the start of the experiment. At that time every one of the machines cleaned with the sodium metaphosphate detergent mixture was free from milkstone on both the metal and rubber surfaces, and the machines were pronounced perfectly clean. On the other hand, many of the control machines were heavily coated with milkstone, particularly in the rubber hose lines.

CONCLUSION

The experiments cited show that the use of a detergent mixture containing sodium metaphosphate prevented the formation of milkstone on both the metal and rubber parts of the milking machines. The use of milking machines kept free of milkstone deposits made it possible to produce a lower count milk than was produced with the machines containing milkstone.

REFERENCES

(1) MALLMANN, W. L., AND CHANDLER, W. L. On the disinfection of avian fecal material. J. Am. Vet. M. Ass., 83: 190. 1933.

(2) SCHWARTZ, CHARLES, AND GILMORE, B. H. Sodium metaphosphate in mechanical dishwashing. Indust. & Eng. Chem., 26: 998–1001. 1934.

(3) GILMORE, B. H. Prevention of calcium deposits in process waters. Indust. & Eng. Chem., 29: 584–590. 1937.

A REVIEW OF OXIDATION IN MILK AND MILK PRODUCTS AS RELATED TO FLAVOR[1]

W. CARSON BROWN[2] AND L. M. THURSTON[3]
West Virginia Agricultural Experiment Station, Morgantown, W. Va.

I. INTRODUCTION

Tallowy, oily and fishy flavors, which are considered to be caused by oxidation, have been observed in storage butter since the early days of the industry. The objectionable nature of these off-flavors caused losses which drew the attention of investigators to the problem of their prevention. Early investigations showed that air (152, 192, 194, 318), light (152, 192, 194, 305, 318, 383) contamination by metals (11, 164, 209, 230, 392), acidity of the cream (131, 241, 242, 274, 275, 322) salt content of the butter (131), and storage temperature (131, 192, 194) all are factors related to the development of these flavor defects. Later work showed that several other factors may promote the oxidative changes in butter which affect flavor.

More recently work on oxidation in milk products other than butter has been stimulated by investigations of the effects of metals on these products. Examples of this type of investigation are the work of Hunziker and associates (180, 181, 182) which showed that certain metals, particularly copper and iron, dissolve in the milk brought into contact with their surfaces and cause undesirable flavors; the work of Rice (288) which showed that tallowiness in sweetened condensed milk may be caused by copper contamination resulting from contact of the milk with copper in vacuum pans; and, the report of Okuyama (260) which showed that copper contamination of milk during processing, rather than contact of the milk with the bottle cap, was causing so-called cappy flavor in the milks from four milk plants under the control of his laboratory.

Examination of the literature available at the present time shows that many of the factors which favor oxidative changes in butter are concerned also with the production of off-flavors in milk, dried milk, ice cream, and condensed milk. Since a given factor may produce oxidative changes in more than one dairy product, each factor, as it relates to various dairy products, will be discussed separately.

II. EFFECT OF MICRO-ORGANISMS

Butter—In 1894 Von Klecki (383), studying rancidity and the acid number of butter, observed that bacteria caused an increase in acidity.

[1] Published with the approval of the Director of West Virginia Agricultural Experiment Station as Scientific Paper No. 236.

[2] Department of Dairy Husbandry.

[3] Department of Animal Husbandry, University of Florida. Deceased February 29, 1940.

Probably this increase was not related to oxidative changes because later work by Sayer and associates (322), Rogers and co-workers (306, 307), and Stokoe (343) shows that micro-organisms are not associated with the development of oily and tallowy flavors in butter. However, Ritter and Christen (299) have found that active cultures of certain alkali-producing bacteria retard the development of fishiness in butter, perhaps by retarding or reducing acidity (see Sect. VII).

Milk and Cream—The relation of micro-organisms to the development of off-flavors in the fluid products, milk, cream, and ice cream, is quite different. Kende (198) has shown that the addition of a culture of bacteria which grew well at temperatures below 10° C. prevented the development of oxidized flavor in milk. Kertesz (200) isolated this species and gave it the name *Reducto-bacterium Frigidum neutrale.* A preparation of this culture has been made in dry form by drying milk which has been sterilized and inoculated. According to Ritter and Christen (296) the dry culture is effective in preventing oxidized flavor when added to milk or cream in a proportion of 1 to 25,000. They examined this preparation and found that it does not reduce methylene blue but does reduce 2, 6-dichlorophenol-indophenol; and that the active material can be obtained from milk sugar by extraction with alcohol or ether. They were able to isolate 5 to 7 per cent of hydroquinone from the dry material and considered this substance to be the active antioxidant. Kertesz (201) replied to Ritter and Christen stating that hydroquinone is known to be a product of the metabolism of certain bacteria and pointing out that it has no harmful physiological effects. He stated also that the reducing bacteria are not of a single type, but are embraced within a group whose individual types vary in the production of reducing compounds.

Tracy (363) states that oxidized flavor develops more rapidly at 4° than at 20° C. and Thurston and Olson (361) noticed an oxidized flavor in milk which had been stored for several days at 38° F. and which showed little bacterial growth, whereas a duplicate sample of the same milk stored at 52° F. showed considerable bacterial growth but no oxidized flavor. Roland, Sorensen, and Whitaker (310) found that bacterial counts of milk which showed oxidized flavor were generally lower than the counts of milk free from this defect. Tracy, Ramsey and Ruehe (366) extended information on the subject when they reported that oxidized flavor was less likely to occur in milk incubated at 68° to 90° F. for 1 to 6 hours before cooling and holding at 40° F. than was the case when milk was stored at 40° F. immediately without incubation. Cream which had a tendency to develop oxidized flavor without incubation, when incubated showed a higher average score of about 3.5 points. They also found that the addition of living yeast cells to milk retarded the development of tallowiness, whereas the addition of dead cells had no effect.

Esselen (98) found that the growth of bacteria significantly retards the oxidation of ascorbic acid, especially when cultured in media containing fermentable carbohydrates.

There is considerable evidence to show that the retarding effect of the growth of micro-organisms on the development of oxidized flavor in milk and cream accompanies and is usually parallel with a lowering of the oxidation-reduction potential. This has been shown by Kende (198) and by Tracy and co-workers (366). The work of Thornton and co-workers (354, 354a) and of Fay and Aikins (1, 102) on the methylene blue reduction test shows that the growth of micro-organisms in milk causes a lowering of its oxidation-reduction potential. This effect appears to be the result of the removal of dissolved oxygen by bacterial growth and the influence of natural reducing substances in the milk. The effect of absorbed oxygen was shown in an interesting way by Jackson (189) who found that milk drawn anaerobically from the udder of the cow reduced methylene blue almost instantaneously, whereas the same milk exposed to the air under normal conditions usually required more than 10 hours to reduce the dye. Strynadka and Thornton (344) found that abnormal udder conditions responsible for milk of high leucocyte content also were responsible for abnormally high concentrations of reducing substances in milk, although they observed that in common practice leucocytes are rarely, if ever, the main or significant influence in the reduction of methylene blue in milk. Davis (79) showed reduction of several dyes in ripened cheddar cheese, apparently brought about by the growth of bacteria.

III. EFFECT OF METALS

Iron and Copper Contamination—Weigmann (392) was one of the first to observe the catalytic effect of iron in the oxidation of butter fat. In 1891 he attributed oily flavor in butter to iron which contaminated the cream kept in poorly tinned vessels for creaming. Marcas and Huyge (230) noted a bitter, astringent taste in the butter from milk kept in rusted iron cans, whereas milk held in non-rusted cans was of good quality. They found that cream having a normal iron content of 0.005 parts per 1,000 would increase to 0.240 parts after 22 hours contact with a rusted can, and to 0.270 parts per thousand after 46 hours. The butter from cream containing 0.240 parts per thousand contained 0.080 parts of iron per thousand of cream. Butter made from cream containing 0.270 parts per thousand contained 0.134. They concluded that the cream coming in contact with iron rust formed a lactate from the iron oxide and that the lactate was responsible for the bitter taste observed. The solvent action was found to be especially pronounced in cream of high acidity. Hoft (164) made butter from cream which stood for 22 hours after the addition of 2 to 33 parts per million of ferrous ammonium sulfate. In the majority of the eight butters on which the report was based,

an oily metallic taste was observed. He made the significant observation that small amounts of iron acting for a long time had more effect than larger quantities acting for a shorter time.

The effect of washing butter with water containing iron has been studied. Kooper (209) using a suspension of finely divided metallic iron in the water reported no effect on the butter washed with water containing iron in quantities up to 36 mg. of iron per liter. He believed that changes which may take place are caused by other substances in the water together with the iron and suggested that these substances probably are hydrogen sulfide or nitrous acid. The addition of rusted nails or pulverized iron rust to cream before ripening caused oily and metallic flavors in the butter. Another investigator (11) reported that 9 to 15 mg. of soluble iron per liter of wash water caused oily and metallic flavors in the butter and that butter washed with water from which iron had been removed by oxidation and filtration did not show off-flavors. However, this investigator agrees with Kooper (209) in regard to the production of oily and metallic flavors by cream held in rusted vessels. Our present knowledge would lead us to believe that solubility is paramount in this connection.

Rogers and associates (307) added copper and ferrous iron in the form of lactates or sulfates to cream and observed that distinct oily, metallic or fishy flavors developed in the butter after churning. The copper caused more intense flavors than did the iron.

In 1917 Hunziker and Hosman (183) found that copper, as well as iron, catalyzed the development of tallowy flavor in butter. Either an iron nail or a copper wire imbedded in the butter caused bleaching and tallowiness. The addition of colloidal hydroxides of iron and of copper in minute quantities to butter (4 drops per 180 grams of butter) was tried with the result that the copper-contaminated sample became tallowy in 8 days, whereas the iron-contaminated sample did not show this defect after two months in storage at 32° F. Pure butter fat emulsified with casein and a slight excess of alkali showed slight tallowiness and bleaching after 5 days at room temperature in the presence of iron, copper, brass, or German silver. These samples were intensely tallowy and bleached after 28 days. Samples containing nickel and tin, which were normal after 5 days, had turned slightly tallowy without bleaching, and the butter fat of normal lactose content emulsified without acid, alkali or metal addition remained normal. The iron-contaminated sample containing alkali became fishy. In all cases of bleaching and tallowiness observed by these workers the defects appeared first at the surface of the butter and developed inward. Later Hunziker (178) pointed out that the use of copper or German silver equipment in the processing of cream when the cream also was exposed to the action of air and light yielded butter which would develop a metallic, oily or fishy flavor.

Singleton (331) states that the great majority of creamery butter in New Zealand has an iron content well below the maximum desirable figure of 1.5

p.p.m. but that a much higher proportion of the samples had a copper content exceeding the desirable maximum of 0.2 p.p.m.

Miwa (244) reports that the copper content of dried milks vary with brands and that the maximum content was 0.03 mg. per 10 grams while the minimum was 0.02 mg. In addition he reported that Japanese dried milk contained more copper than other foreign makes. Hunziker (177) observed that the metallic flavor often found in sweetened condensed milk was due to the formation of copper oxide in the dome of the vacuum pan, and that when the copper, both in the pan and in its dome, were kept clean, bright, and shining, the product was practically free from a metallic taste.

Emery and Henley (97) found that lard, corn oil, and cottonseed oil developed rancidity (oxidative) when stored in copper or iron containers and that lacquering the containers prevented this development. Clavel (49) warned that metals such as iron which dissolved when fats are stored in metal tanks or containers catalyze the reaction causing rancidity.

In 1905 Golding and Feilman (125) reported that milk passed over a partially detinned cooler acquired a metallic flavor after about 18 hours. No doubt the so-called metallic flavor was identical with that referred to as oxidized flavor at present for the catalytic effect is indicated by the fact that 18 hours intervened between contamination and development of the flavor. Little attention was given to the oxy-catalytic effect of copper in milk, however, until attention was focused on the effects of metals on milk and of milk on metals by the work of Hunziker (180) in 1925. Hunziker pointed out that there were then many cases on record where the use of copper-coil suface coolers in milk plants had caused the milk to develop a disagreeable metallic flavor. In most of these cases the tin coating on the copper was defective and retinning invariably prevented further trouble. Hunziker cites numerous cases in which copper-bearing equipment had been known to cause development of undesirable flavor in milk. He reported also that iron contamination of milk produced similar effects although to a lesser degree. In 1927 Okuyama (260) showed that a cappy or pulpy flavor, noticed at four different milk plants, was caused by copper contamination.

The effect of copper contamination on the flavor of milk brought to attention the natural copper content of milk as a possible cause of oxidized flavor. In 1922, Supplee and Bellis (346) reported uncontaminated milk to contain 0.04 mg. of copper per 100 grams. Later work has indicated this figure to be too high although workers are not in agreement as to the amount of copper present. One group of workers (93, 116, 244) have found the average copper content of milk to be about 0.3 mg. per liter. Other workers (62, 210, 211, 412) report the natural copper content of milk to be 0.14 to 0.17 mg. per liter. These results indicate the need for accurate and reliable methods for the determination of copper in minute amounts.

Likewise, results vary as to the amounts of iron found naturally in milk. Davies (83) reported the iron content of uncontaminated milk to vary

between 1.18 and 2.32 p.p.m., whereas Dahlberg and Carpenter (63) reported an average of 0.379 mg. per kg. Over the course of a year, Krauss and Washburn (211) reported the iron content of milk to vary between 0.34 and 0.43 mg. per liter. Guthrie and Brueckner (142) found that certain cow's milk developed oxidized flavor without metallic contamination.

Evidently as better methods become available, better agreement on the mineral content of milk will be obtained. Echave (93) obtained a slight increase in the copper content of milk produced on feeds high in copper. However, Liebscher (219) was unable to increase the copper content of milk by feeding beet tops treated with copper. Rice and Miscall (289), in 1923, were two of the earliest workers to determine experimentally the amount of corrosion of copper by milk. They used a procedure in which copper strips were immersed in milk under various conditions and determined the amount of corrosion by loss of weight. Many workers have used this procedure with minor variations.

Temperature was one of the first factors shown to influence the rate of corrosion. Rice and Miscall showed that less copper was dissolved at boiling temperature than at room temperature. Whitfield *et al.* (402) reported greater corrosion at 144° F. than at 60° F. Gebhardt and Sommer (117, 118, 119) showed that the solubility of copper increased up to 158° F. and then decreased. Trebler *et al.* (369) found greater corrosion of copper, nickel, and nickel-silver in milk at 140° F. than at 158° F. Miscall and co-workers (243) found that the dissolving power of milk increased up to 140–145° F. and then decreased. Quam (283) working with copper in milk at temperatures ranging in 9° intervals between 86° and 212° F. reported the maximum corrosion at 185–194° F.

The presence of oxygen has been shown to increase the rate of copper corrosion, whereas the presence of carbon dioxide decreased it (117, 118, 119, 243, 289, 402). Copper with an oxidized surface shows an increased amount of corrosion (289). Henderson and Roadhouse (155) reported lower rates of corrosions for copper in alloys containing tin and zinc.

Many workers (104, 119, 145, 214, 240, 282, 293, 369, 396, 402) have observed high corrosion rates for nickel exposed to the action of milk and an oxidized flavor has been observed in one instance (145), a metallic flavor in another (402) and an off-flavor in still another instance (293). In the last case the off-flavor was not tallowy when compared to the copper-induced flavor.

Aluminum (104, 119, 144, 145, 181, 213, 282, 293, 396, 402) has been shown to withstand corrosion by milk and does not give off-flavors. However, aluminum is readily corroded by alkali washing powders (181).

Chromium-nickel steel, stainless steel, and Allegheny metal (119, 144, 181, 182, 281, 369, 396, 402) withstand corrosion by milk and produce no off-flavors in the milk.

Galvanic effects can occur wherever dissimilar metals are coupled in hot, aerated pasteurized milk. Likewise, galvanic corrosion can occur solely as a result of a difference in temperature of identical metal surfaces exposed to a given solution. These effects are well known, and certain metal couplings are avoided. Wesley, Trebler, and LaQue (396) prepared a cell with a nickel electrode in milk and studied the effect of temperature variations. They concluded that the temperature effect is of little importance under pasteurization conditions, and that in this instance the galvanic effect of differential aeration can be of greater importance than that of temperature difference.

Fink and Rohrman (104) have demonstrated that nickel may replace copper in solution during pasteurization and that the resulting pasteurized milk may be lower in copper content than the milk prior to pasteurization.

Ellenberger and White (94) observed a metallic flavor in cream pasteurized in contact with copper and stored for six months at 0° F. Guthrie (141) observed that metallic flavors were caused by factors other than the direct contact of the cream with the metal. He observed that cream only slightly metallic in flavor yielded buttermilk with a strong metallic flavor even when churned in a glass churn. Rogers, Berg, Potteiger, and Davis (307) studied the factors influencing the change of flavor in storage butter and observed that ferrous sulfate or ferrous lactate added to cream prior to churning caused a distinct off-flavor described as oily, metallic or fishy. Copper sulfate and copper lactate produced these results much more intensely than the ferrous salts. Hunziker and Hosman (183) and Hunziker (178) verified the findings that metallic and oily flavors were related to either iron or copper contamination. They likewise observed that copper was more active than iron in bringing about this defect.

In addition to oily, metallic, and tallowy flavors of butter, fishy flavor appears to be closely correlated with iron and copper contamination. In 1923 Sommer (335) reported before the World's Dairy Congress that trimethylamine is the immediate cause of fishiness in butter and that it is produced mainly, if not entirely, by the chemical decomposition of lecithin. In a discussion of Sommer's paper Hunziker characterized tallowiness and fishiness as closely related flavors. He regarded both as arising from the same combination of factors with the exception of the acid reaction which accompanies fishy flavor.

The development of fishiness in butter (193) like that of tallowy flavor in cream (298) appears to be retarded or reduced by high temperature pasteurization. Likewise bacteria which reduce the oxygen content of butter (193) or cream (297, 298) retard or inhibit these flavor defects.

Since the off-flavors are believed to be due to oxidation the factors affecting the oxidation of butterfat have received increasing attention. In 1931 Briggs (27) showed that certain metallic catalysts exerted a great influence

in hastening the reaction. Ultra violet light, hydrogen peroxide, and fat peroxides had a strong pro-oxidative effect and lactic acid had a similar but less pronounced effect. The presence of curd exerted an anti-oxygenic effect, but glycerol, triolein, lactose, iodine, potassium iodide, high humidity and pasteuriaztion had little or no influence. Henderson and Roadhouse (154) have shown that direct sunlight increases the percentages of unsaturated fats in the milk fat.

The form which copper takes in milk and milk products has been the object of different investigations. Osborne and Leavenworth (266) and Vandevelde (381) have shown that copper combines with the proteins. This combination seems to be a matter of adsorption rather than direct chemical combination. Most investigators believe that the copper ion acts in some way to catalyze the reaction whereby an oxidized flavor is produced. Smythe and Schmidt (334) have reported data which suggest that those substances which possess a particular grouping within the molecule will hold iron as an undissociated compound. Smythe (333) has presented a theory for the mechanism of iron catalysts. Warburg (385) and Goard and Rideal (124) believe that in oxidations by ferrous salts, the ferrous iron forms a peroxide and that this peroxide is the oxidant. Davies (84) has shown that iron and copper distribute themselves between cream and separated milk in proportion to the curd nitrogen, but upon complete centrifugation of the fat a higher concentration of metals occurs in the cream, indicating adsorption of complex proteinates at the fat-globule surface. The exact mechanism whereby either copper or iron catalyzes the off-flavor produced in milk and milk products is not as yet adequately explained.

As already mentioned Golding and Feilman (125) were probably the first to report the effect of copper on the flavor of milk. Since that time the effect of copper and iron on milk flavor have been noted by a large number of investigators (30, 45, 61, 63, 83, 88, 122, 126, 133, 141, 198, 212, 232, 245, 246, 276, 293, 300, 337, 342, 391). This flavor has been variously characterized as cappy, cardboard, oxidized, papery, metallic, metallic and oily, emery, oleagenious, and tallowy. It is generally agreed that this flavor is the result of oxidation and the term "oxidized" is now generally used.

Because of the importance of copper in milk Ritter (292) developed a test for copper based upon the peroxide reaction. Turgeon, Stebnitz and Sommer (379) modified this test slightly and found (380) that vitamin C complicated its application. Herrington and Brereton (158) developed a flame test for determining the presence of copper in a metal or alloy.

Sommer (335) has reported that fishy flavor in butter is the result of the production of trimethylamine from the lecithin. High acid, high salt, overworking, and the presence of iron or copper are factors favoring fishiness. Iron and copper salts act as oxidative catalysts. In comments following Sommer's paper, Hunziker states that he regards fishy and tallowy flavors

as being closely related in that both result from much the same combination of factors. Ritter and Christen (297) and Jensen and Ritter (193) also have shown that copper and iron contamination favor fishiness in butter fat but the former workers observed notable exceptions which indicated that other factors were involved. Horrall and Epple (176) have recently developed a modification of Ritter's test for copper in butter.

It has been known for some time that subsequent to the contamination of milk with copper, iron, or both, oxidized flavor may develop. The presence of these metals as contaminants does not always cause oxidized flavor, however, and the exceptions will be discussed in connection with the effects of feed of the cow and effects of processing (Sections VI and XI).

Induction Period and Peroxide Value—Considerable information has been gained by the use of the induction period method of Greenbank and Holm (137a), sometimes with minor variations. This method consists in maintaining fat at 95° C. in a gas-tight flask with agitation under an atmosphere of oxygen and measuring the amount of oxygen absorbed by the fat. Fats subjected to this treatment usually do not take up any considerable amounts of oxygen for some time. This period is called the induction period. At the end of the induction period rapid oxygen absorption begins. The length of the induction period is considered to be a measure of the resistance of a fat to oxidation. This method permits study of the effects of various added substances on the susceptibility of the fat to oxidation. Wright and Overman (409) found that the induction period of one butter fat was reduced from 32 hours to one hour when it was contaminated with copper. Briggs (27) found that the presence of certain metallic compounds shortens the induction period in decreasing order as follows: sodium vanadate, copper lactate, iron lactate, and nickel sulfate. He found that zinc lactate, on the other hand, increased the induction period slightly. Henderson and Roadhouse (154) added copper to milk, allowed it to stand for some time and found that the induction period of the fat of the milk had been reduced. A slight reduction was produced by nickel also, whereas 18–8 chromium-nickel steel produced no change.

The peroxide value of fats, as outlined by Wheeler (397), also has been used as a means of measuring the progress of oxidation. This method is based on the liberation of iodine from potassium iodide by peroxides formed in the fat. Since peroxides form during the oxidation of a fat, this value is considered to be an excellent indicator of the progress of the reaction. Ritter and Nussbaumer (301) found that copper added to butterfat accelerates peroxide formation in the presence of light. Later they reported (302) that small amounts of copper palmitate caused a large increase of peroxide value but large amounts caused little or no change. They found also that in butter which is tallowy already, increased amounts of copper inhibit peroxide formation, especially in the presence of heat and light.

Ritter and Nussbaumer (301, 302) have shown that the peroxide number of fat is a measure of its content of active oxygen, and therefore of its tendency to undergo oxidation. Their data show an increase in the peroxide number of a fat in the presence of light (especially in an unsaturated fat), air, copper, and a high temperature; a decrease in peroxide number occurs when 0.1 to 1.0 per cent of hydroquinone is added. Peroxide number was markedly reduced by heating butter fat at 195° and at 250° C., but such heating destroyed anti-oxidative properties, resulting in a marked increase in peroxide number upon later storage. Measuring the increase in peroxide number upon storage for 8 hours at 104° C. was an easy and reliable method of determining the keeping quality of butter. When air was passed through heated butterfat, the peroxide number increased rapidly. Copper in the form of fat-soluble copper palmitate, accelerates the assimilation of oxygen and increases accordingly the peroxide number of the fat, when it is stored in the dark at normal temperature. The higher the storing temperature, the more rapid was the increase of the peroxide number. The lower the peroxide number in this test the less the tendency for the fat to oxidize. When fat is being oxidized under the influence of heat there is a distinct increase in weight. Fats extracted according to the Roese-Gottlieb method very often show an extremely rapid increase in the peroxide number. Ritter and Nussbaumer demonstrated that the addition of increasing quantities of fat-soluble copper palmitate to butter fat caused the peroxide number to increase. The peroxide number increased more rapidly during storage of the fat in the dark at ordinary room temperature, as the concentration of copper palmitate increased within the chosen range of 0.000,001 to 0.33 per cent. On the other hand, when the copper containing fat was stored at ordinary room temperature in the light, it showed a slower increase in the peroxide number than fat which was free from copper. Later on the peroxide number of the butter fat contaminated with copper decreased in spite of a continued exposure to light. This was not the case with the copper-free fat.

On heating the samples during 8 hours at 104° C., fats which contained about 0.000,1 per cent of copper palmitate revealed the greatest increase, and fats with a greater copper content showed a lesser increase, of the peroxide number. The reason for this phenomenon is that copper not only accelerates the assimilation of oxygen to increase the peroxide number, but also hastens the further conversion of the fat peroxides. That is why the peroxide number decreases again in the presence of greater amounts of copper as well as in the presence of light and warmth. Moreover, a distinctly tallowy butter fat, when heated at 104° C. for 8 hours, gave a decreased peroxide number as the amount of copper palmitate added was increased. The nature of this second state of copper catalysis which brings about the destruction of the fat peroxides is not fully understood.

Wright and Overman (409) have shown an induction period of nearly 32 hours for fresh butter fat as compared with 5 hours for a 2 year old fat, 3

hours for butter fat containing 1 per cent lactic acid, and less than 1 hour for butter fats contaminated with copper. Temperature was found to accelerate oxidation of butter fat in proportion to the height of the temperature.

A great amount of work has been done on the various factors affecting rancidity (oxidative) in fats. Emery and Henley (97) have shown that air, oxygen alone or in combination, light, and metals are among the factors which influence the development of rancidity. Streaming CO_2 as a source of inert gas was found ineffective. Salkowski (318) regarded the development of rancidity in lard and butter fat as due to the combined activity of oxygen and light, and as a direct oxidation process in which the oxygen consumption could be measured. He believed that the speed of the reaction depended upon the intensity of the light and that little oxygen was consumed in the absence of light.

MacLean and Pearce (226) have shown that hydrogen peroxide with oleic acid in the presence of a copper catalyst brings about oxidation first at the 9th and 10th carbon atoms and then proceeds further in the 18-carbon chain. The oxygenated chain then breaks up. Succinic and oxalic were the only dibasic acids isolated. The 8 terminal carbon atoms of the oleic acid chain are broken off, and the remaining part of the chain appears to be completely broken up. The copper salt greatly increased the extent of oxidation. Clavel (49) studied the oxidation of oleins and concluded that there is a relationship between the drop in the iodine number of fats during storage and the adsorption of oxygen causing rancidity. Metals such as iron which are dissolved when fats are stored in metal tanks or containers catalyze the reaction.

The manner in which the oxidation of the fat takes place has been the subject for much speculation. Weiland and Franke (393, 394, 395) suggest that hydrogen peroxide can be used as the oxidant in studying the oxidation of organic acids in the presence of ferrous salts. Their conclusions are that the ferrous ion unites with the substrate thereby making the latter more susceptible to oxidation. On the other hand Warburg (385) and Goard and Rideal (124) believe that in oxidations by ferrous salts the ferrous ion forms a peroxide and that this peroxide is the oxidant.

Just what the mechanism is whereby the action of metals on the oxidation of fats is produced is difficult to demonstrate experimentally. However, the effect of metals on the quality of the product is well known and it is deemed advisable to keep the metal content as low as possible.

Oxidation-Reduction Potentials—One of the earliest works showing a relationship between oxidized flavor development and oxidation-reduction potential was made by Tracy, Ramsey, and Ruehe (366) in 1933. They showed that the normal tendency for freshly drawn milk was to shift toward a lower potential but that the addition of copper caused a shift toward higher potential. This was later verified by Thurston (355), Webb and Hileman (387)

and Greenbank (135). Thurston showed that iron, like copper, invariably raised the oxidation-reduction potential of the milk when an oxidized flavor was produced. His results showed that salts of tin and aluminum, when added to milk, produced a lower potential than that of normal milk and did not cause an oxidized flavor. Webb and Hileman (388) and Greenbank (136) showed that by the addition of copper and subsequent observation of the potential it was possible to predict, to a fair degree of accuracy, those samples which later become oxidized. Greenbank (135) has shown that a change from dry to green feed is paralleled by a decrease in oxidation-reduction potential and by an increase in the poising action (see Section VII "Effect of Feed"). It was his belief that the thermal inhibition of the flavor acted through a lowering of the oxidation-reduction potential. Webb and Hileman (387) have shown that summer milk does not develop oxidized flavors even in the presence of a high oxidation-reduction potential. Thornton and Hastings (354) and Fay and Aikins (102) found that the time curves of milk with and without methylene blue were in close agreement. Likewise, it was found by Kende (198) that milk which developed an oxidized flavor had a long reduction time as judged by methylene blue. Aikins and Fay (1) have shown that fat plays an important role in potential changes and that sunlight causes a drift toward lower potential. Likewise, light in the visible spectrum reduces methylene blue (189). Thornton and Hastings (354a) believe that reduction in milk is accompanied by the removal of oxygen by bacteria. Tracy and co-workers (366) have shown that incubation of milk prior to contamination with metal reduces the tendency for oxidized flavor to develop. Recently Strynadka and Thornton (344) have shown that abnormal udder conditions for milk with high leucocyte content were also responsible for abnormally high concentrations of reducing substances in milk.

Since it appears that anything which tends to lower the oxidation-reduction potential, tends to prevent the occurrence of oxidized flavor, it appears that many factors may indirectly or directly be involved in the development of oxidized flavor.

Off-flavor in Ice Cream—Tallowy or oxidized flavor in ice cream has attracted the attention of many different research workers (24, 69, 70, 73, 225, 314, 315, 365). Although tallowy flavor is generally associated with strawberry ice cream Ross (314) has pointed out that it may occur in any kind of ice cream but may be masked by the flavoring. The work of Dahle and Josephson (73) shows that vanilla ice cream will develop a tallowy flavor but that it will not acquire this flavor as readily as strawberry ice cream. Mack and Fellers (225) concluded the rapid flavor deterioration in strawberry ice cream was the result of oxidation of the butter fat. Working along this same line Ross (314) was unable to determine any changes in the degree of oxidation of fats of a magnitude that could be detected by the usual chemical

technique. The trend of the flavor development indicated that fat oxidation might be the cause of the defect. However, oxygen adsorption, as measured by the test for oxidase, gave no proof that oxidizing agents had any part in the flavor development. Iverson (188) states that the trend in iodine number of the fat points toward oxidation during the development of the off-flavor. Bird and co-workers (24) found a tendency for the drop in iodine numbers of the fats to be greatest in the samples which develop the defect most rapidly. Iverson (188) was unable to find any correlation between the initial and final Reichert-Meisel numbers and (the actual values were determined on the extracted fat at the beginning of the trial and after 60 days of storage) the development of the off-flavor.

Certain factors are related to the development of tallowy flavor in strawberry ice cream. Chief among these seems to be the presence of metallic salts (71, 188, 225, 365). Roundy and Jackson (315) observed that when condensed mixes were stored for 3 months and then made into ice cream, the lots made from mixes condensed in copper pans were criticized twice as often as those made in stainless steel or nickel pans. Ross (314) reports that iron does not seem to be a factor whereas Iverson (24, 188) found that samples high in iron showed a reduced tendency to develop an oxidized flavor. He suggested that possibly the iron was combined in the ferrous form and served as an anti-oxidant.

Mack and Fellers (225) reported that strawberries contain enzymes which aid in developing this off-flavor but Iverson and co-workers (24, 188) found that the oxidases introduced by the fruit are not the cause of the off-flavor. They found that if the berries were soaked in the mix before freezing the flavor development was retarded. Likewise, increasing the amount of fruit used has been found to retard the onset of tallowy flavor (71, 365, 367). Tracy, Ramsey and Ruehe (367) offer the explanation that the strawberries contain two agents affecting fat oxidation, one contained in the juice which serves as a catalyst while the other in the fiber serves as a reducing agent. Dahle and co-workers (69, 71) found that the off-flavor may occur as readily in pineapple ice cream as in strawberry and that the heating of berries and the ice cream mix to 180° F. for one hour did not prevent the development of this off-flavor. These results would lead one to believe that factors other than the oxidases in the fruit are responsible for the onset of this defect.

In their pioneer work Mack and Fellers (225) reported that the acid nature of the strawberries induced off-flavor development. This observation was borne out by the work of Dahle and Folkers (71) who reported the neutralization of the acid in strawberries delayed the onset of tallowy flavor. However, Tracy, Ramsey and Ruehe (367) reported that an increased citric acid content of the berries did not hasten or delay the onset of the flavor.

Dahle and Folkers reported in 1932 that no "cardboard" flavor developed in ice cream where dry skim milks were used in mixing formulas but

that it did occur in most samples containing condensed skim milk. This observation was later confirmed by Ross (314). He observed that samples made with condensed skim milk contained more copper and developed the cardboard flavor before similar samples made with dried skim milk. These results might be expected because larger amounts of solids were introduced by the condensed milk which probably contained more copper than the dried skim milk.

Dahle and Folkers (71) reported that the use of cardboard flavored milk or skim milk had little effect on the flavor of the ice cream but that sufficient copper was introduced through the condensed milk to cause the flavor. They observed that when the pans were kept well polished no off-flavors resulted. Bird and co-workers (24) reported that the copper content of dry skim milk samples ranged from 0.20 to 1.08 p.p.m. and the condensed skim milk samples ranged from 0.24 to 2.12 p.p.m. of copper. However, their results showed that ice cream made with dry skim milk as a source of serum solids developed oxidized flavors to a greater extent than those containing condensed skim milk. Ice creams made from condensed skim milk containing 2.7 p.p.m. of copper often developed oxidized flavor while on the other hand similar samples prepared from skim milk condensed in stainless steel pans did not show oxidized flavors. In the range between 1.18 and 1.8 p.p.m. of copper no predictions could be made as to the development of oxidized flavor defects. Apparently the state of the copper is more important than the total amount of copper present.

Flavor Defects in Condensed Milk—There is ample evidence to show that copper is detrimental to the flavor of condensed milk. Hunziker (177) and Rice (288) have pointed out that the manufacture of sweetened condensed milk in vacuum pans that have a coating of copper oxide on them results in a metallic- or tallowy-flavored product. The results of Rice indicate that the reaction is of a chemical nature and that the presence of air or oxygen greatly accelerates the rate of flavor development. Since condensed skim milk is much lower in fat content and much lower in flavor development than condensed whole milk the conclusion was reached that the flavor was the result of oxidation of the fat. Rice was able to produce tallowy flavor by adding copper and iron tartrate. Copper produced a much stronger flavor than iron and on this basis iron was believed to be of minor importance in the production of tallowy flavors in condensed milk. Both Genin (120) and Donauer (91) have observed the effect of copper on the flavor of condensed milk. Genin concluded on the basis of corrosion tests that practically all metals other than copper constitute better materials for the construction of evaporating pans. A factor which operates automatically to check the corrosion of metals in contact with the milk product being processed is the formation of a protective milk film. This protective film is less effective in the case of copper. Roundy and Jackson (315) observed that

although copper dissolved in the use of copper vacuum pans nevertheless it did not affect either the flavor or the keeping quality of evaporated milk. On the other hand Sommer and Gebhardt (337) found the flavor and color of evaporated milk impaired in direct proportion to the amount of copper present. They found appreciable amounts of copper dissolved in the making of Swiss cheese but reported no flavor defects due to the increased copper in this product.

IV. EFFECT OF AIR AND OXYGEN

Butter and Butter Fat—In 1890 Ritsert (305) reported rancidification as an oxidative change which required only the presence of oxygen and which could be accelerated by light. Later work (38, 192) showed that in addition to air, light and warmth greatly accelerated the rate of the reaction. As the result of his studies Jensen (194) came to the conclusion that air was important in butter deterioration only when accompanied by sunlight and high temperature. These results (192) indicate that olein is the point of attack when oxidation takes place.

Barnicoat (14) showed that practically no oxidation of butter fat occurred at 80° F. in an air pressure of 0.04 inches of mercury. Some inhibition of oxidation was noted in proportion to the extent of the vacuum used, at pressures of 3 to 10 inches, as compared to normal air pressure. Butter fat packed in tins under reduced air pressure was preferred to butter packed in and stored at atmospheric pressure for 3 to 6 months at 14° F. Flavor defects, when present, were mainly at the surface of the butter.

Hanus (152) observed that under the influence of air and light the saponification equivalent and the acid number of butter fat increased, whereas the iodine number decreased, and the Reichert-Meissl number remained unchanged. Butter subjected to the action of air and light gradually lost its yellow color, became lardy in appearance, smelled very rancid and had a sharp, tallowy taste. Nestrelayev (258) observed that butters from different parts of the country differed in their susceptibility to the action of light and air. The larger the content of unsaturated acid present the greater was the effect of light and air. The greatest changes produced by the action of light and air were in the Koeststorfer number, the average molecular weight of the non-volatile acids, and in the iodine adsorption number.

Browne (39) studied the spontaneous decomposition of butter fat over a period of 28 years by means of loosely stoppered samples and found a marked increase in the content of free and volatile acids and a considerable decrease in the content of insoluble acids. He advanced the theory that the disintegration of the fats was primarily due to the action of active or nascent oxygen, one atom of which was liberated for each atom absorbed at the points of unsaturation. Greenbank (134) obtained a negative Kreis test on butter fat following the removal of the free fatty acids by means of steam distillation, stored under vacuum in diffused light for three years. His study of the

effect of heat and air upon the oxidation of fats in the absence of light showed a fall in the induction period after 3 months from 248 minutes to 41 minutes.

Gray (131) observed that butter packed in full cans kept better than butter packed in partially filled cans. He attributed this difference to the action of air. In a discussion arising over the benefits to be derived from carbonation of butter Hunziker (179) reported that if butter is properly made it will have equally as good keeping qualities whether or not it is carbonated. Emery and Henley (97) found streaming CO_2, as a source of inert gas, ineffective in preventing rancidity. However, Prucha, Brannon, and Ruehe (280) reported that the storage of butter in an atmosphere of CO_2 in tightly-sealed cans improved its keeping qualities, in that storage flavors did not develop as soon as in air and that mold growth was prevented. Since oxygen is necessary for the reaction whereby rancid and tallowy flavors are produced its seems reasonable to believe that the exclusion of oxygen would reduce or eliminate the development of these flavors.

Salkowski (318) in studying the rancidity of lard and butter fat believed it to be the result of the combined activity of oxygen and light, and that it was a direct oxidation process in which the oxygen consumption could be measured. Siegfield (329) studied the oxidation of butter fat and found that fresh fat exposed to light and air for 3 months increased in weight about 1 per cent and that the acidity increased nearly four fold. In addition he found increased Reichert-Meissl, saponfication, and Polenske numbers, and a decrease in the iodine number. Holm (165, 167) studied the amount of gas taken up in the oxidation of fresh butter fat and found that an induction period was necessary before the oxygen was absorbed. Following the induction period oxygen was absorbed in a logarithmic manner. Determinations of acidity, iodine number, iodine liberated from potassium iodide in 24 hours, and Kreis tests were made. Of these determinations only the Kreis test gave results which would detect small differences in the degree of oxidation. He found no relation between oxygen absorbed and olfactory detection. A mixture of heptylic aldehyde and pelargonic acid added to fresh butter fat gave a tallowy taste but no Kries test.

Rogers *et al.* (307) used an especially designed apparatus and found that the volume of gas in freshly made butter was approximately 10 per cent by volume. Of this, 33 per cent was nitrogen, 20 per cent was oxygen and the remainder was absorbable by sodium hydroxide. They found the oxygen content was materially reduced after storage.

Aspegren (12) studied atmospheric oxidation and found that during exposure at 145° F. the nitrogen increased and the iodine number decreased.

Sommer (335) found that air was related to fishiness in butter. Overworking of butter tended to increase the air content of the butter and thus to increase the oxygen available for the oxidative production of trimethylamine.

Dried and Fluid Milk—Holm (165) found that tallowiness appeared first in samples of dry milk with the lowest moisture content. The dry product

of approximately 2 per cent moisture and the spray product of approximately 3 per cent moisture were found to be optimum for delaying tallowy flavors and odors. Samples above 4 per cent in moisture content always developed a fishy flavor. Whether or not the butter fat would absorb oxygen rapidly was found to depend not so much upon the quantity of oxygen available as upon the susceptibility of the fat. He pointed out that very small amounts of oxygen are necessary for the progress of oxidation. Somewhat contrary to what might be expected Holm *et al.* (171) found that in a five-month storage period air storage was best, vacuum storage was second and carbon dioxide storage was the poorest of the three methods, as judged by the induction period. These workers concluded that the inherent keeping quality of the fat was more important than the nature of the atmosphere in which it was stored.

Dahle and Palmer (76) found that milk powders high in moisture rapidly became tallowy when stored in moist air. They emphasized the point that containers most be absolutely tight to outside air and moisture to insure good keeping qualities. Palmer and Dahle (271) found that practically all the granules in spray process dried milk contained air cells and that the onset of talloviness was found to be proportional to the size of the air cell. Coutts (59) also reported drum process powders superior to spray process in keeping quality.

Greenbank (133) has reported that aeration of milk increases the copper-tolerance of the milk. He found that aeration plus pasteurization gives the greatest protection against oxidized flavors. This does not appear to agree with the findings of Dahle and Palmer (78) who found that they could inhibit the development of oxidized flavor by the removal of oxygen. However, Brown, Tracy and Prucha (37) found that cappy or tallowy flavors usually developed more rapidly in vacuum capped milk. (This vacuum was insufficient to remove the dissolved oxygen). Hand *et al.* (143, 151) showed that the development of oxidized flavor could be largely or completely prevented by a process of vacuum cooling whereby the dissolved oxygen was largely removed from the milk. From these results it would appear that dissolved oxygen plays an important role in the development of oxidized flavor in milk. However, the amount of oxygen required to produce the off-flavor is very small and in order to prevent its development the oxygen apparently must be almost completely removed.

Tracy (362) reported a surface taint developed on frozen whipped cream in the hardening room. He described these odors as being absorbed from the air in the hardening room.

Although no work has been reported on the effect of air or oxygen on the development of oxidized flavor or tallowy flavor in ice cream, nevertheless oxygen might be expected to play a similar role in this product. The nature of the product is such as to insure an adequate amount of oxygen present for

the development of these off-flavors which would be expected to appear whenever other conditions were suitable. Here lower temperature evidently plays a role and aids in slowing down the rate of development of oxidized flavor.

V. EFFECT OF LIGHT

Butter and Butter Fat—In 1894 Von Klecki (383) observed that butter must be kept away from direct sunlight and at a low temperature to maintain its quality. About five years later Hanus (152) noted that butter subjected to the action of air and light gradually lost its yellow color, smelled very rancid, and had a tallowy taste. This was accompanied by an increase in acid number, and a decrease in iodine number. Nestrelayev (258) found that butters from different parts of the country differed in their susceptibility to change with exposure to air and light depending upon the content of unsaturated acids. Reinmann (287) expressed the opinion that light was not as important in causing rancidity as claimed by some investigators. Since that time various workers have observed the effect of light (27, 29, 38, 97, 103, 134, 154, 192, 202, 215, 218, 301, 302, 318, 329) and it has been established that light does have an important accelerating effect on fat oxidation. Ruemele (316) pointed out that it is the action of light and the composition of the fatty acid mixtures which determine the speed of fat spoilage. Stebnitz and Sommer (338) have shown that butter oil will oxidize by high temperature aeration in the absence of light, to produce a tallowy flavor in 3 hours. By use of ultra-violet light a tallowy flavor was produced in 15 minutes. The flavor produced by light differed somewhat from that produced by aeration alone. Sunlight likewise produced a tallowy flavor in 15 minutes, while diffused sunlight required 12½ hours to produce a tallowy flavor. Lamp light (100-watt at 10 cm.) gave a tallowy flavor after 4 days, whereas infra-red light did not cause a tallowy flavor in 14 hours, at which time the experiment was discontinued due to rise in temperature of the fat.

These findings have focused attention on the types of wrapping material used as a means of light control (17, 324). Davies (85) found that as a general rule the depth of color was more important than the actual color, in preventing oxidation. He observed that light blue was the least effective in preventing oxidation. This finding was verified by Morgan (248). Greenbank and Holm (138) in studying the relative accelerating effect of light of different parts of the visible spectrum on autoxidation of cottonseed oil, found the greatest acceleration in the range of the orange band. Holm, Greenbank, and Deysher (170) found that ultra-violet light had a powerful effect on the susceptibility of fat to autoxidation as judged by the induction period. Stutz, Nelson and Schmutz (345), reported that the effective region of light was limited to blue and the ultra-violet range as judged by the production of hydrogen peroxide. Coe (50, 51, 52), and Coe and LeClerc (53, 54, 55) found that selective ultra-violet light hastens the development of

rancidity as compared with natural sunlight. They found black and green containers a practical and effective means of protecting certain food materials against rancidity. Barnicoat (16) recommended the use of dim electric lights in packing rooms and the use of heavy grade parchment wrappers as a means of controlling light defects in butter.

Zilva (411) found that butter could be entirely bleached by exposure to ultra-violet light. In this process it became tallowy and lost its vitamin A value. Baumann and Steenbock (19) working with carrots and tomatoes found that pure carotene and vitamin A were destroyed by exposure to ultra-violet light but that crude carotene was entirely stable under the conditions of the experiment. Baumann and Steenbock (20) found that the maximum absorption of light in butter oil occurs at 460 and 485 mu. This is the point in the spectrum where carotene is determined by light absorption. Apparently carotene plays an important role in the effect of light on the autoxidation of butter fat, since butter is bleached in color prior to active oxidation as judged by the induction period.

Milk and Cream—The effect of light on milk was brought to the attention of investigators as early as 1907 by Burr (43). He reported that the exposure of milk in glass bottles to direct sunlight hastened its deterioration. He did not state the nature of the defect involved, but suggested the use of green, red, or black bottles. He also suggested the use of colored paper over plain bottles to hold back the injurious blue and violet rays. In 1930 Hammer and Cordes (150) reported that a tallowy flavor developed in milk following its exposure to sunlight in plain glass bottles, and that the development of this flavor was hastened by the presence of copper or iron known to be in the milk. Skimmilk developed a burnt flavor upon exposure but this flavor was not related to metallic salts and was not characterized as "tallowy." The exposure of milk in plain glass bottles to diffused light caused only a tallowy flavor, whereas the exposure of milk in brown glass to direct sunlight was without effect on flavor.

These early reports have focused the attention of investigators on the effect of light on milk. More recently the effect of sunlight on the flavor of milk has been noted by several workers (45, 107, 231, 232, 233, 276, 356). Marquardt (231) reports a bleaching effect from the exposure of milk to sunlight for 2 or more hours and an oxidized flavor after 20 to 60 minutes exposure followed by 24 hours storage. Greenbank (135) reports that light may inhibit, promote, or have no effect on the development of oxidized flavor, the results depending upon the contamination and the intensity of irradiation. Whitehead (400) studying the reduction of methylene blue found that methylene blue added to good quality milk reduced in a short time in the presence of sunlight but in darkness no decoloration resulted in 7 hours. This reaction was not due to an enzyme since it proceeded equally well in milk that had been heated at 100° C. for 30 minutes. The reduction of

methylene blue does not take place in skim milk (1, 44, 400) and for this reason it was believed related to the fat. Sodium oleate will restore the reaction while sodium palmitate does not restore it. It was suggested that sunlight catalyses the oxidation-reduction reaction in which unsaturated fats are oxidized and the methylene blue is reduced. Aikins and Fay (1), Jackson (189) and Buruiana (44) have observed the reduction of methylene blue by light. In addition to this Aikins and Fay observed that artificial light produced the same effect except to a lesser degree. These latter findings did not verify the results of Whitehead (401) who was unable to reproduce the effect of sunlight by use of either ultra-violet radiation or radiation from electric lamps. Davies (82) reports that exposure of milk to the radiation of a mercury-vapor lamp for 2 minutes was sufficient to change the flavor and shorten the induction period. This shortening of the induction period by exposure to ultra-violet light was verified by Anderson and Triebold (2). Genin (121) reported no loss of vitamin A from ultra-violet irradiation of condensed milks. Flake, Weckel and Jackson (106) found that it was possible to remove the activated flavor produced by irradiation by the addition of 2 or 3 p.p.m. of copper followed by bubbling air through the milk at 140–145° F. In addition, the odor of irradiated milk could be duplicated by irradiation of an aqueous solution of egg white or gelatin. This indicated that the protein fraction of milk was probably the parent substance of the flavor and that it probably was identical with the burnt flavor found by Hammer and Cordes (150). Because of the similarity between the burnt or activated flavor produced by sunlight and the tallowy or oxidized flavor which likewise is catalyzed by sunlight and the action of metals, considerable confusion has occurred in the literature due to terminology. Weckel and coworkers (390) found that it was feasible to irradiate the separated fat portions of the milk and to reconstitute the milk. In this way the reconstituted milk was relatively free from activated flavors.

Kon and Watson (208) have reported that light oxidized the ascorbic acid in milk. Their results show that light of short wave lengths is mainly responsible for this action. Ultra-violet light showed some activity while red and yellow lights were almost without effect. The replacing of the dissolved oxygen with an inert gas prevented the action of light. More recently Kon (207) reports that under the action of light the ascorbic acid of milk undergoes reversible oxidation, most probably to dehydroascorbic acid. He reports that the power of ascorbic acid to reduce indophenol, lost through exposure to light, can be restored to an extent varying with the length of exposure by treating the milk with hydrogen sulfide. Hopkins' (175) work gives a clue as to the mechanism by which light destroys the vitamin C in milk. In the presence of light, lactoflavin rapidly causes the destruction of vitamin C, there being a simultaneous degradation of lactoflavin to lumichrome. The work of Hand, Guthrie and Sharp (151) verifies this mecha-

nism. They observed that after the lactoflavin and ascorbic acid are destroyed by prolonged exposure to sunlight, any additional ascorbic acid added to the milk is relatively stable. The sensitivity of ascorbic acid to light can be restored by the addition of lactoflavin to the milk.

Guthrie, Hand and Sharp (143) report a general relationship between the factors which accelerate the rate of oxidation of ascorbic acid and the production of oxidized flavor. The effect of sunlight in causing the oxidation of ascorbic acid is due to the photosensitizing action of the lactoflavin and the presence of oxygen in the milk. Paper bottles markedly decrease the effect of sunlight on the oxidation of ascorbic acid and on the production of off-flavors.

Doan and Myers (90) studied the effect of sunlight on some milk and cream products. Paper bottles, of the type used, offered appreciable protection to skim milk, whole milk and butter milk against the action of sunlight in producing burnt flavors as compared to the use of clear glass bottles. The paper bottles were of no protection to whole milk, cream, or homogenized whole milk against tallowy flavors caused by sunlight. Blue and green colored paper bottles or blue and green cellophane wrappers on glass bottles retarded the development of tallowiness and burnt flavors. They found that the degree of tallowy flavor produced in milk and cream by sunlight was stronger in the paper bottles than in the clear glass bottles.

Apparently light plays a role in the development of oxidized flavor in milk and cream both by its effect on the carotene content and by its indirect effect through lactoflavin and vitamin C.

VI. EFFECT OF FEED GIVEN THE COW

Composition of Fat—One of the early investigations of the effect of feed on butter fat was made by Hunziker, Mills and Spitzer (184) in 1912. Their work showed that feeding cows rations high in linseed oil meal or cottonseed meal will increase the iodine number of the fat. Henderson and Roadhouse (154) found that when animals are on submaintenance rations they draw upon their body fat for milk production and thereby increase the percentage of unsaturated fats in the milk and increase the susceptibility of the fat to oxidation. Hening and Dahlberg (156) found that feeding cows at a level below the Morrison standard did not influence either the flavor of the milk or the percentage occurrence of oxidized flavor in the milk. Hill and Palmer (160) found that when barley constituted from 35 to 50 per cent of a low-fat diet containing alfalfa or timothy hay a hard butter fat with a low iodine value was produced. Dahle and Carson (69) report that cows fed alfalfa hay produced milk more susceptible to oxidized flavor than cows on other roughages. Hill and Palmer reported that the inclusion of oils or fats in the ration resulted in butter fat which assumed some of the characteristics of the oil fed. Linseed oil in the ration significantly increased the content of fatty

acids less saturated than oleic acid. Prewitt and Parfitt (278) found that rations containing soybean oil, either as such or in the unprocessed beans, had a tendency to produce milk which upon holding developed less intense oxidized flavor than did milk from cows fed other rations. Dean and Hilditch (86) found that when cows went on grass there was an abrupt increase in the oleic and linoleic acids and a parallel reduction of butyric and stearic acids in the butter fat.

Green and Dry Feed—One of the earliest workers to report a seasonal variation in oxidized flavor was Mattick (237) who in 1927 reported that oiliness in milk appeared in autumn, winter and spring, but never in the summer. Kende (198) recognized this fact and as the result of his work concluded that green feed contained some substance or substances which when fed to the cow protected the milk against the off-flavor. Since that time numerous workers (31, 40, 64, 135, 142, 276, 279, 355, 364, 372) have observed the difference in susceptibility of winter and summer milk to oxidized flavor. Stebnitz and Sommer (340) found that when cows received grass as part of their ration, the butter fat became less saturated and more susceptible to oxidation. However, it appeared that protective substances in the milk prevented the development of oxidized flavor. Green feeds (13, 31, 64, 78, 198, 355, 356) have been shown to yield a more stable milk as compared to milk produced on dry feed. Majer (227) has shown that the following action of beet forage can be prevented by the addition to the ration of fresh Alp hay. In contrast to this, Hening and Dahlberg (157) reported that the feeding of mangels or beet pulp in no way prevented or increased the susceptibility of milk to oxidized flavor development.

Vitamin C and Carotene—The nature of the inhibiting substances carried in green feed has been the object of extensive investigations. The first clues as to the probable nature of these substances were found by Ritter (291) and Chilson (47) in 1935 when they found that the addition of ascorbic acid to the milk prevented the development of oxidized flavor. These findings were verified by Sharp, Trout, and Guthrie (328) and by Dahle (64, 78). Sharp *et al.* found a positive correlation between the rate of oxidation of ascorbic acid and the rate of development of oxidized flavor. Trout and Gjessing (374) found the percentage decrease of ascorbic acid upon storage greater in the winter than in the spring, summer or fall. Brown, Thurston and Dustman (31) found that the feeding of one quart per animal per day of either tomato or lemon juice to cows on dry feed reduced the susceptibility of milks to oxidized flavor development. They attributed this effect to the ascorbic acid in the feed and observed a similar tendency when pure crystalline ascorbic acid was fed at the rate of ½ gram daily. Riddell *et al.* (290) found 25.8 mg. of ascorbic acid per liter of milk produced by cows on a dry ration plus silage, 26.5 mg. per liter by cows on dry ration alone, and 26.5 mg. per liter by cows on pasture alone. Rasmus-

sen and others (285) found that the stage of lactation appeared to have a more definite effect upon the ascorbic acid content of the milk than did breed differences. The ascorbic acid content of milk was found to be relatively high during the early stages of lactation, but decreased to a minimum after about two months of lactation and then increased to a maximum in the later stages of lactation. Brueckner and Guthrie (40) found no relation between the period of lactation and the development of oxidized flavors. Whitnah, Martin and Beck (403) ranked the breeds in descending order according to the average vitamin C content of the milk as Jersey, Guernsey, Ayrshire, and Holstein. The frequency with which spontaneous oxidized flavor occurred in their study was in the reverse order. Garrett, Tucker, and Button (115) found that the average flavor scores show that for each ascorbic acid class interval where a decrease of acid occurs, a decrease in flavor score also occurs. They found the apparent critical point of relationship of ascorbic acid and good flavor to lie between 15 and 18 mg. of ascorbic acid per liter of milk. Beck, Whitnah and Martin (22), however, found no relation between the amount of vitamin C in the original milk or the amount of vitamin C lost during storage and the development of oxidized flavor in milk. These findings appear to be somewhat at variance with the findings of Sharp, Trout and Guthrie (328). Dahle (64) likewise found that when oxidized flavor occurs naturally in milk the ascorbic acid is greatly reduced.

Garrett, Tucker and Button (115) found a close relationship between percentage of fat and color, between color and the first day ascorbic acid content, and between color and first day flavor. It was their belief that both carotene and ascorbic acid had reducing properties and that they acted in this way to exert protective action on the milk.

Garrett, Arnold and Hartman (112) reported that the feeding of grass silage had a greater stabilizing effect on ascorbic acid in milk than corn silage or beet pulp. This stabilizing effect tended toward milk of better flavor.

Whitnah, Martin and Beck (403) found that within the breed there was no relation between the amount of vitamin C present and the development of oxidized flavors from individual cows. All samples which developed oxidized flavor were below the breed average in intensity of fat color. However, they found samples low in color which did not develop oxidized flavor. They were able to reduce oxidized flavor by feeding 2 pounds of dehydrated oats (young plants) containing 103 mg. of carotene per pound. The flavor defect was completely eliminated by feeding a carotene concentrate containing 150 mg. of carotene per pound.

Anderson (6, 7, 8) and co-workers (10) were some of the earliest workers to show the effect of carotene on the flavor of milk. Their work showed that carrots or machine-cured alfalfa fed to cows would eliminate oxidized flavor in their milk. This they correlated with the carotene content of the feed.

Anderson, Hardenbergh and Wilson (9) obtained far more effective results in the elimination of oxidized flavor from the feeding of 8 pounds of carrots in the daily ration than was obtained from the addition of 500,000 U. S. P. units of vitamin A. Whitnah, Peterson, Atkeson, and Cave (404, 405) and Beck, Whitnah and Martin (22) report that a carotene supplement quickly corrected the tendency for an oxidized flavor to develop spontaneously. Brown, VanLandingham and Weakley (35) found that a carotene supplement added to the ration rendered the milk less susceptible to metal-induced oxidized flavor. Likewise, it was their finding that supplementing a low carotene ration with ascorbic acid produced similar results. Martin (233) reports that to minimize the occurrence of milk with oxidized flavor the milk should be kept normal with respect to carotene content. Dahle (67) was unable to delay the onset of oxidized flavor by the direct addition of carotene to the butter fat.

Booth *et al.* (25) found a close agreement between the amount of green material in the diet of the cow and the carotene and vitamin A content of the butter fat. It was concluded that the vitamin A activity of the summer butter fat appeared to be three times greater than that of winter fat, and that the fraction of total activity due to carotene was also greater in summer butter fat. Hilton, Hauge, and Wilbur (161) found that under winter feeding conditions timothy hay produced a butter low in vitamin A value, while good quality alfalfa or soybean hay were effective either in maintaining the high vitamin level of butter or in restoring its summer value. They found that the vitamin A value of butter responded rapidly to changes in the ingestion of vitamin A by the cows. Baumann and co-workers (21) found variations in vitamin A content of as much as 100 per cent between individuals of the same breed. They found that 3.3 per cent of the vitamin A ingested on a low carotene ration was recovered in the milk, but that only 1.3 per cent was recovered from a high carotene ration. Loy *et al.* (222) found that 11 days were required to reach an equilibrium on a carotene depletion ration and that during the repletion period the rise was quite rapid and reached an equilibrium level in about 10 days. Tucker, Garrett and Bender (378) found a close correlation between high yellow color and good flavor in milk. They reported that grass silage was superior to either corn silage or beet pulp in the production of good flavored milk. In a later work (113) they suggest the use of grass silage as a method of rendering milk less susceptible to oxidized flavor. Hodgson, Knott and Murer (163) found that hays were a poor source of vitamin A while silages and grass were the best sources. The carotene content of the butter fat accounted for only 11.2 to 12.7 per cent of the total vitamin A activity. Henderson (153) in a review of literature points out the desirability of having winter rations high in carotene content.

Thurston (356, 357) reviewed the literature on oxidized flavor and suggested the following classification for milks from the standpoint of oxidized flavors.

1. *Spontaneous milk*—Milk capable of developing oxidized flavor spontaneously, *i.e.*, without the presence of iron or copper as a contaminant.

2. *Susceptible milk*—Milk which does not develop oxidized flavor spontaneously, but is susceptible if copper or iron contamination occurs.

3. *Non-susceptible milk*—Milk which will not become oxidized even when contaminated with iron or copper.

Since both vitamin A and carotene have been reported to have antioxidant properties (see section XIV) any factors which affect these substances may have a relation to oxidized flavor. In 1920 Hopkins (174) reported a rapid destruction of vitamin A by heat and aeration. Matill (234) found that the oxidative changes which accompany the beginning and development of rancidity in unsaturated animal fats tend to destroy vitamins A and E. This process is hastened by ferrous iron. Simmonds *et al.* (330) observed the so-called salt ophthalmia in animals fed rations containing ferrous sulphate. A cure was effected when rations were made up daily. Jones (195) observed the same effect and believed it due to the iron catalyzing the oxidative destruction of vitamin A. McCollum *et al.* (239) confirmed this finding. Marcus (229) believes that the destruction of vitamin A by granulated lactose is an autoxidation in which hydroquinone prolongs the induction period. Taylor (351) reported both vitamin A and E destroyed by ferrous chloride.

Hilton, Hauge and Wilbur (161) found good quality alfalfa or soybean hay were effective either in maintaining a high vitamin A level in butter or in restoring it to its summer value. The vitamin A value in butter responded rapidly to changes in the ingestion of vitamin A by the cows. Hodgson and co-workers (163) found home grown field cured hay the poorest source of vitamin A of the different roughages tested. Bartlett *et al.* (18) found that kale and artificially dried grass markedly increased the vitamin A content of the milk but that sprouted maize and mangels had little effect.

In general it appears that both ascorbic acid and carotene are related to the susceptibility of the milk to oxidized flavor. Ascorbic acid acts either from its presence in the feed or by being placed directly into the milk. From the results available it does not appear that vitamin C in the feed passes directly into the milk to prevent the flavor. However, it probably acts in some way as a stabilizer for the vitamin C secreted in the milk. Carotene apparently must be in the feed in order to effect the susceptibility of the milk. Both of these substances have reducing properties and it is possible that through these properties they may affect the susceptibility of the milk to oxidized flavor.

VII. EFFECT OF ACID

Cream and Butter—In the early days of the butter industry, butter made from sour or ripened cream was believed to have superior keeping qualities to sweet cream butter. As early as 1890 Patrick (274) was studying the alleged poor keeping qualities of sweet cream butter. Later, Patrick, Leighton and Bisbee (275) found that sweet cream butter retained its flavor better than butter made from sour cream. In 1904 Michels (242) reported that butter of the best keeping quality was obtained from well ripened cream. He recognized, however, that if the ripening process was carried too far undesirable keeping qualities would result. McKay and Larsen (241) state that in the ripening process the lactic acid bacteria suppress the other types which if carried into the butter would produce undesirable changes. Wiley (407) observed less deterioration in butter made from cream acidified with lactic acid than in butter made from cream ripened to the same pH. McKay and Larsen recognized the danger of carrying the ripening process too far. Many research workers (27, 92, 147, 165, 220, 223, 267, 268, 384, 399) have noted the detrimental effect of ripening cream on the keeping quality of the butter. Mortensen (251) found that the per cent acid in cream was inversely proportional to the keeping quality. He also observed that proper neutralization gave good results. Flake (105) found that butter falling within the range of pH 6.0 to 6.49 had better keeping qualities than did butter of either higher or lower hydrogen ion concentration. Ellington (95) found that a serum pH of 7.0 or over indicated a low quality of butter due to over-neutralization or low quality raw material. Overman *et al.* (268) found no differences in keeping quality due to use of different neutralizers. However, over-neutralization resulted in low initial scores and low keeping quality. That pH has an effect on the rate of oxidation of fat, in general, has been shown by the work of Lea (216). He found the rate of oxidation of lards showed a sharp increase as the reaction became alkaline. Apparently this explains the effect of over-neutralization in butter.

Rogers and co-workers (308, 309) found that acidity was an important factor in the development of fishy flavor in stored butter. The work of Ritter (294) verified these findings. Ritter and Christen (299) found that certain alkali producing bacteria retarded the development of fishiness in butter. Haglund and Walker (148) found that the tendency to develop fishy flavor could be reduced by partial neutralization of the acid in ripened cream. In 1923 Sommer (335) found that fishy flavor in butter was the result of the chemical decomposition of lecithin with the production of trimethylamine as the immediate cause. The work of Jensen and Ritter (193) showed the development of fishy flavor to be brought about by hydrolysis and oxidation of the lecithin. At about the same time Holm, Wright, White, and Deysher (172) correlated the deterioration of butter in storage with a score below 89, with chemical changes. These changes were

brought about by oxidation. From these results it would appear that acidity plays an important role in the deterioration of butter which under some conditions appears to be the result of oxidation.

Milk—Anderson (3) and co-workers (5) found a relationship between apparent acidity and the susceptibility of milk to oxidized flavor. It is generally known that winter milk is higher in acidity than summer milk and that winter milk is more susceptible to oxidized flavor than is summer milk. They observed that the neutralization of high acid milk to 0.145 per cent acidity or lower was effective in the prevention of oxidized flavor. Likewise, they observed that high acid milk invariably developed an oxidized flavor after pasteurization. In a study of 220 individual samples of winter milk, Brown and Dustman (33, 34) were unable to find any correlation between the acidity of freshly drawn milk and its tendency to develop oxidized flavor when contaminated with copper. They were unable to prevent the development of oxidized flavor by neutralization to 0.13 per cent titratable acidity or in a small number of cases to as low as 0.10 per cent. These workers were unable to offer any explanation as to the disagreement of their results with those of Anderson and his co-workers other than the fact that Brown and Dustman added the copper from a solution of copper sulphate, whereas Anderson and co-workers depended upon contamination from the equipment as a source of copper. From a theoretical point of view it seems unlikely that natural acidity plays an important role in the development of oxidized flavor in milk when copper contamination takes place.

VIII. EFFECT OF MOISTURE

Butter and Butter Fat—In 1915 Hyland and Lloyd (185a) found that the complete oxidation of fat was possible in dry air, whereas moist air prevented oxidation of glycerides and assisted oxidation of free fatty acids. Later Fierz-David (103) expressed the belief that rancidity was produced by air, light, and water without the action of bacteria; that unsaturated fatty acids were split into aldehydes and acids; and that fats containing saturated fatty acids were oxidized to the corresponding methyl alkyl ketones. Brochot (29) reported that for cold storage of butter the condensed water from the cold surfaces in the storage chamber should be eliminated as far as possible. He emphasized the importance of low-humidity in the butter cold storage chamber. Holm (165) using an oxygen absorption method found that the presence of water in a fat extended the induction period. Ritter and Nussbaumer (303) explained these results on the basis that butter serum must contain some substance or substances which retard the oxidation of the butter fat. They found that the rate of oxidation of pure butter fat was scarcely affected by the addition of a quantity of water equal to that contained in butter. From their results it would appear that in butter the moisture itself does not play as important a role as does the material which

it carries. Ritter and Nussbaumer explained this effect on the basis of the cephalin and lecithin content of the serum. Both of these substances exhibit antioxidative properties.

Dried Milk—Dahle and Palmer (76) reported that milk powders high in moisture and stored in moist air rapidly became tallowy. Davis (80) likewise, reported that for a milk powder to possess good keeping qualities it must be low in moisture. In contrast to these results, Holm, Wright and Greenbank (171) found that in general more rapid deterioration occurred in samples of low moisture content. In another study Holm (165) found that an increase in the moisture content of a milk powder not only retarded oxidation but prevented the formation of those intermediate products which gave rise to a tallowy odor.

IX. EFFECT OF SALT IN BUTTER

In 1903 Buhl (41) reported that light salting of butter had an advantage over heavy salting in the keeping quality of butter. Gray and McKay (131) likewise found that butter containing low percentages of salt kept better than butters containing high percentages of salt. Washburn and Dahlberg (386) reported that salt exclusive of its antiseptic property hastened deterioration of butter. Oily, metallic and fishy flavors showed up to a greater extent in salted than in unsalted butter. Guthrie, Scheib and Stark (146) reported that salt in butter greatly retards bacterial growth. Butters containing no salt were prone to become old or stale but seldom oily. These findings presumably can be attributed to inhibited bacterial growth since the storage was carried out at 10° C. Kildee (203) reported that salt accelerated the deterioration of butter at temperatures which check bacterial growth but at higher temperatures the salt inhibits the growth of the bacteria and thus preserves butter. The work of Overman and co-workers (267, 268) showed that salted sweet cream butter had a slightly higher initial score but lost score more rapidly than unsalted sweet cream butter.

The results for butter storage are not clear cut. Sayer *et al.* (322) used a storage temperature of about 5° F. and reported no differences in keeping quality for butter with salt contents from 1.06 to 3.78 per cent. Rann, Brown and Smith (284) reported that salted butter keeps better than unsalted butter above the freezing point as well as below. Jacobsen (191) reported that the destructive action of salt apparently was of greater importance than freezing in reducing the number of bacteria in salted butter. Flake (105) found little or no relation between salt concentration and keeping quality, except in the samples which contained less than 2 per cent salt. Here there was a slight decrease in keeping quality.

Since high salt concentration is associated with the development of fishy flavor and since fishy flavor apparently is the result of hydrolysis and oxidation of lecithin, it would seem that salt tends to favor oxidative changes.

X. EFFECT OF STORAGE TEMPERATURE

In 1894 Von Klecki (383) reported that storage butter should be kept at a low temperature to prevent deterioration. Thomsen (353) reported that butter from good cream kept better than butter from poor quality cream. Barnicoat (15) found that freezing temperatures are superior to chilling temperatures for butter storage. Likewise, he (16) found that butter is more susceptible to color and flavor defects when held at relatively high temperatures. Rogers, Thompson and Kiethley (309) stored butter at 0, 10, and 20° F. Of these three temperatures the best results were obtained at 0° and the poorest at 20° F. Gray and McKay (131) stored butter at – 10, 10 and 32° F. and found that butter kept best at – 10° F. Holm and co-workers (172) reported that drop in storage temperature from – 10 to – 17° F. does not result in an increase in keeping quality proportionate to that observed by a similar lowering at a higher temperature range. Ellis (96) found that at 75° C. stearic acid shows appreciable autoxidation under certain conditions of dispersion and catalysis. Wright and Overman (409) found increase in temperature to accelerate oxidation of butter fat in proportion to the height of the temperature.

From these results it would appear that temperature has a direct bearing upon the rate of oxidation of butter. The higher the temperature the more rapid the rate of oxidation.

Dahle and Palmer (76) reported that "tallowy" and "stale" are the outstanding flavor defects in dry milk powders. They found that storage at 4 to 20° C. gave about equal results with sealed tin containers but that 37° C. was too high.

Scism (326) found that ice cream kept better at – 25° F. as compared to retail cabinet temperature. The very nature of the product insures a low temperature during storage and a dipping temperature that is within a relatively narrow range.

When cream is stored, the exact temperature does not appear to be of great importance compared with metallic contamination, as shown by numerous investigations (94, 249, 250, 321, 342).

The effect of storage temperature on the susceptibility of milk to oxidized flavor has not been determined as such for the reason that it is obscured by the effect of bacterial growth at 50° F. or above. (See section II.)

XI. EFFECT OF PROCESSING

Milk, Cream, and Butter—The effect of heat in the processing of cream has been the object of extensive investigation. White and Campbell (398) found that pasteurizing cream at temperatures between 145 and 165° F. did not improve the keeping quality of the butter as judged by the score. On the other hand, Guthrie, Scheib and Stark (146) found that pasteurization of cream at 165° F. produced butter of better keeping quality than pasteuriza-

tion at 145° F. They attributed this result to the destruction of oxidases at 165° F. whereas, they stated only lipase is destroyed at 145° F. Mortensen (251) reported slightly better quality in fresh butter from sour cream pasteurized at 170° F. for 20 minutes, than in butter pasteurized at 145° F. for 30 minutes. However, the butter pasteurized at the lower temperature kept better in storage. Pasteurization at 170° F. for 20 minutes was better than at 180° F. for 20 minutes. Crews (60) reported that pasteurization at 165° F. for 30 minutes destroyed most, if not all, of the harmful milk enzymes. He believed oxidation to be the most important factor in butter deterioration. Ritter (294, 295) found that a fishy flavor could be prevented by flash pasteurization of cream at 90° C. Greenbank and Holm (137) found that heating fat at 100° C. to destroy any enzymes reduced the keeping quality in proportion to the length of heating.

Enzymes have long been considered as a factor in the deterioration of butter. However, with present pasteurization methods the activity of the enzyme lipase has been largely eliminated. In 1904 Rogers (306) reported that deterioration of canned butter was due to enzymes from the milk or enzymes produced by micro-organisms. In 1913 Winckel (408) reported that enzymes and ferments had little, if any, effect on the deterioration of butter in storage. Palmer and Combs (270) found that tallowy flavor in butter resulted from the addition of copper lactate to either raw or pasteurized cream. A pasteurization temperature of 79–80° C. for 15 minutes was used. In a later work Palmer and Miller (272) found by the addition of peroxidase to butter that this enzyme was not a factor in the deterioration of butter. Dahle and Palmer (77) reported the presence of peroxidases in fresh milk powder. However, the factors known to favor oxidation proved detrimental to peroxidase activity. Thacher and Dahlberg (352) were able to show indications of oxidase action in milk by use of pyrogallol. Boiling the milk failed to completely inhibit this action. Proks and Groh (279) reported that lipolytic enzymes were responsible for the development of oily-rancid and tallowy flavors in milk. They found that the degree of off-flavor developed was proportional to the quantity of lipolytic enzyme present.

The belief that oxidized flavor is the result of the action of an enzyme has been based largely upon the fact that milk heated to very high temperatures does not develop the flavor. Kende (198) in 1932 reported that milk heated to 85° C. did not develop an oxidized flavor. He named the enzyme responsible for the flavor "oleinase." Majer (228) was unable to verify the findings of Kende although he did find that the high heat treatment greatly reduced the intensity of the flavor developed. Guthrie and Brueckner (142) reported that pasteurizing at 160° F. or higher for 30 minutes decreased or prevented the tendency for spontaneous oxidized flavor to develop. Dahle (64, 66) reported that heating milk to 145° F. for 30 minutes intensified the oxidized flavor developed but that heating to 170° or above eliminated the

flavor defect. Brown, Thurston and Dustman (30) found that copper added after pasteurization developed a more intense oxidized flavor than copper added prior to the pasteurization process. Gould and Sommer (127) were able to correlate this finding with the development of a cooked flavor in the milk.

The recent work of Gould and Sommer (127) and Gould (128, 129) has shown that sulphur compounds are liberated when a cooked flavor is produced. They were able to develop an oxidized flavor in milk heated to 90° C. These findings tend to disprove the action of an enzyme in the development of oxidized flavor in milk. In addition, the production of a cooked flavor liberates sulfides which act as antioxidants. These findings have been verified by the work of Josephson and Doan (196). Greenbank (135) reported that the thermal inhibition of oxidized flavor acts through a lowering of the oxidation-reduction potential. This has been confirmed by both the work of Gould and Sommer (127) and Josephson and Doan (196), who found that the sulfide compounds, liberated when a cooked flavor develops, lowered the potential.

Whitnah *et al.* (406) reported excessive losses of vitamin C from holding process pasteurization, even when copper contamination was reduced to a minimum. Sharp, Trout and Guthrie (328) reported that low-temperature pasteurization did not accelerate appreciably the destruction of ascorbic acid, provided contamination with copper was prevented. They found a positive correlation between the rate of oxidation of ascorbic acid and the rate of development of oxidized flavor. Sharp (327) believed the destruction of vitamin C in raw and pasteurized milk to be due to the action of an oxidizing enzyme which is destroyed at temperatures higher than pasteurizing temperature. Since both the development of oxidized flavor and the oxidation of ascorbic acid are prevented by high temperature pasteurization, it seems possible that the development of a cooked flavor with the production of reducing substances also may play a role in the oxidation of ascorbic acid.

Homogenization of milk was first reported to retard the development of oxidized flavor by Tracy, Ramsey and Ruehe (366) in 1933. Since that time Thurston, Brown and Dustman (360), Ross (313) and Dahle (67) have observed the deterrent effect of homogenization on the development of oxidized flavor. Trout and Gould (373) reported that homogenization did not retard the development of oxidized flavor when high rates of copper contamination occurred. This probably explains the tallowy flavor observed by Doan (89) in homogenized milk.

Thurston, Brown and Dustman (360) reported that prolonged agitation at a low temperature, and freezing followed by thawing reduced or eliminated the susceptibility of milk to oxidized flavor development. Their work showed that prolonged agitation of milk at low temperature caused a transfer of the lecithin from the fat globule surface to the plasma portion of the

milk. It was their belief that lecithin in the plasma portion would not become oxidized readily under normal conditions and hence the oxidized flavor failed to develop fully after these treatments.

Dahlberg and Carpenter (63) found that the development of oxidized flavor in pasteurized milk was accelerated by contact with a clean copper-alloy metal, especially following chlorine sterilization, but this effect became less as more milk continued to pass through the equipment. Tracy and Ruehe (368) reported that chlorine sterilizers added to milk containing copper hastens the development of tallowy flavor. Grant (130) found that certain chlorine sterilizers greatly accelerated the rate of corrosion.

Ice Cream and Condensed Milk—Oxidized or tallowy flavor has long been a serious defect in strawberry ice cream. Seism (326) and Schricker (325) reported that chocolate ice cream has superior keeping quality to vanilla and that strawberry has the poorest keeping quality of these three ice creams. Various attempts have been made to avoid the development of oxidized flavor by variations in the percentage of fruit used and by various treatments of the fruit. Dahle and Folkers (71) and Tracy *et al.* (365, 367) reported that increased amounts of berries used in the ice cream delayed the onset of tallowy flavor. Tracy and co-workers found that soaking the fruit in the mix prior to freezing also delayed the onset of the flavor. Likewise, it was their finding that heating the berries at 150, 175, 200° F. and autoclaving at 15 pounds pressure for 15 minutes, decreased progressively the flavor defect. However, they were unable to eliminate the flavor by this procedure. Likewise, Dahle and Folker (71) were unable to eliminate the flavor by heating the mix and berries at 180° F. for one hour. They reported that neutralizing the berries to pH of 7.0 delayed the appearance of the tallowy flavor but injured the flavor of the berries.

Mack and Fellers (225) reported that enzymes contained in the fruit may be a factor in the development of a tallowy flavor. Tracy, Ramsey and Ruehe (367) found that oranges, lemons, pineapples, apples, peaches, and apricots cause the flavor when used in 3 to 10 per cent quantities. When used in large (25 per cent) quantities these fruits like strawberries did not cause the flavor to develop. The enzyme oxidase has been found in practically all of these fruits (101, 286). Mudge and Tucker (254) reported that strawberries which had been aerated by drawing air through them for a considerable time produced a stale and unclean-flavored ice cream. Ross (314) studying oxygen absorption, as measured by the test for oxidase, found no proof that oxidizing agents had any part in the development of the off-flavor. Iverson (187, 188), and Bird and co-workers (24) reported that oxidases from the fruit do not cause the oxidized flavor to develop. These results, together with the finding that extreme heating of the berries does not eliminate the undesirable flavor, suggest that this defect is caused by factors other than the presence of an oxidative enzyme.

The inhibiting effect of homogenization on the development of stale, metallic flavors in ice cream has been noted by Dahle and coworkers (69, 73) and by Tracy, Ramsey and Ruehe (365, 367).

Tallowiness in condensed milk has been noted by various investigators (91, 141, 177, 288). Sommer and Gebhardt (337) reported that evaporated milk was found to be impaired in flavor in direct proportion to the amount of copper present. Holm *et al.* (169) found that as the fat content increased the keeping quality decreased. Homogenization and precondensing were found to improve the keeping quality. Recently Corbett and Tracy (57) reported that condensing milk under vacuum to a concentration of approximately twice the original solids content prevented the development of oxidized flavor in both the condensed milk and the condensed milk reconstituted to the original concentration. These workers used soluble copper at the rate of 3 p.p.m. for contamination They found that the retarding effect of condensing was on the plasma portion of the milk and explained this phenomenon on the basis of liberation in the serum portion of the milk of certain antioxidative constituents that are probably derivatives of the milk proteins. This description seems to fit the sulphhydrils described by Gould and Sommer (127) and by Josephson and Doan (196). Ordinarily one would not expect evaporated milk to develop an oxidized flavor because of the high heat used in sterilization and the homogenization treatment which the milk receives.

XII. COMPOUNDS FORMED AND THEORIES OF THEIR FORMATION

Oxidation Products of Oils and Fats—Scala (323) isolated the decomposition products of rancid fat, and by oxidation with potassium permanganate was able to obtain acids which were separated by means of barium salts.

These acids were identified as oenanthylic, pelargonic, butyric, caprylic and capric, and the conclusion was drawn that rancidity is caused by the presence in the fat of the aldehydes corresponding to these acids.

Vincent (382) concluded that when chemical changes occur in butter the glycerides of the insoluble acids are altered to a greater degree than those of the soluble acids. Canzoneri and Bianchini (46) studying the rancidity of olive oil and the oxidation of oleic acid in sunlight and air found nonylic, azelaic, formic, and dihydroxystearic acids among the products of the oxidation.

Salway (319) oxidized linseed oil at 100° C. in an atmosphere of oxygen and identified acrolein as one of the products. Powick (277) found that all rancid fats and rancid oleic acid gave positive Kreis and peroxide tests. He attributed the Kreis test to the epihydrin aldehyde formed when a rancid fat is brought into contact with concentrated hydrochloric acid. Briggs (28) thought it unlikely that epihydrin aldehyde is formed as believed by

Powick but regarded acrolein as the substance responsible for the Kreis test during the induction period. He suggested also that carotene may be the substance from which the Kreis test arises.

Triebold (370) made a survey of the literature and recognized three general types of fat deterioration, each considered as rancidity, although the processes and end products were different. These three types of deterioration were characterized as oxidative, hydrolytic, and ketonic rancidity. The first of these was considered to be due to the addition of molecular oxygen to unsaturated glycerides with the formation of peroxides which subsequently decompose into aldehydes, ketones, and fatty acids. This type may occur in all edible fats and was regarded as an important type of fat spoilage.

Hydrolytic rancidity is produced by hydrolysis of the glycerides with the liberation of free fatty acids. He regarded this type as important in the spoilage of dairy products.

Ketonic rancidity may develop from fats containing nitrogenous impurities. This results from the action of molds on lower fatty acids with the production of ketones.

It has been thought for a long time that the main factors concerned with fat spoilage are light, air, and moisture. Salkowski (318) believed that the development of rancidity of lard and butter fat was due to the combined activity of oxygen and light, and that it was a direct oxidation process in which the oxygen consumption could be measured. He believed further that the speed of the reaction depended upon the intensity of the light and that little oxygen was consumed in the absence of light. Kerr and Sorber (199) offered the hypothesis that rancidity (oxidative) begins with the entrance of a molecule of oxygen into a molecule of an unsaturated fatty acid, either free or combined, the oxygen molecule attaching itself at the point of double linkage and forming a compound characterized by the peroxide grouping at that point. Tschirch and Barben (377) likewise believed that rancidity starts with the addition of oxygen to the unsaturated acids at the double bond. Subsequently, unstable compounds are formed which break up on hydrolysis to give odorous aldehydes, ketones, and acids. Fierz-David (103) believed that unsaturated fatty acids were split into aldehydes and acids by the action of air, light and water.

Tschirch (376) regarded rancidity as occurring in steps whereby oxygen is added to an unsaturated fatty acid to give a peroxide. The peroxide reacts with water to give an oxide and hydrogen peroxide. Ozone is formed in the presence of hydrogen-peroxide and this reacts with the oxide to give an ozonide. The ozonide is split by the action of water into aldehydes, ketones, and acids. Holm, Greenbank, and Deysher (170) found evidence for the existence of loosely bound oxygen compounds, termed "moloxides," in butter oil. They found ultra violet light to have a powerful effect on the susceptibility of fats to autoxidation. Ellis (96) regarded high dispersion

of the acids as an important factor in the absorption of oxygen by elaidic, oleic, and stearic acids. He found purified, dry sand a good dispersing medium and the cobaltous salt of elaidic acid (0.1 per cent) an efficient catalyst in the autoxidation process. Water and carbon dioxide were evolved during the autoxidation.

Goard and Rideal (124) and Warburg (385) believed that oxidation by ferrous salts resulted from the formation of a peroxide by the ferrous ion, the peroxide acting as an oxidant. Weiland and Franke (393, 394, 395) studied the action of hydrogen peroxide on the oxidation of organic acids in the presence of ferrous salts and concluded that the ferrous ion unites with the substrate thereby making the latter more susceptible to oxidation.

Butter and Butter Fat—Garrett and Overman (114) regarded the oxidation of butter fat as not only a simple addition of oxygen at the double bonds but also as involving the oxidation of saturated acids and probably of glycerine. MacLean and Pearce (226) found that hydrogen peroxide with oleic acid in the presence of a copper catalyst brings about oxidation first at the 9th and 10th carbon atoms, and then proceeds further in the 18-carbon chain. The oxidized chain breaks up. Succinic and oxalic were the only dibasic acids isolated. The 8 terminal carbon atoms of the oleic chain are broken off and the remaining part of the chain appears to be completely broken up. The copper salt greatly increased the extent of oxidation.

That tallowy flavor in butter is the result of oxidation of the fat has been shown by numerous workers. Hanus (152) found that when a tallowy flavor developed the acid number increased and the iodine number decreased, but the Reichert-Meissl number was not materially changed. The work of Jensen (192) indicated that olein is the point of attack in the development of tallowy flavor. Siegfeld (329) reported marked changes taking place in the fatty acids, especially in a decrease of volatile insoluble acids and an increase in the solid non-volatile acids. Lea (215) reported that during the early stages of auto-oxidation and prior to the stage of active oxidation, peroxides are formed and these are an indication of the relative ease with which a fat will produce tallowy flavor. He also reported that bleaching occurred at an early stage in the oxidation. Clavel (49) reported a relationship between the drop in iodine number of fats during storage and the absorption of oxygen causing oxidative rancidity.

Stebnitz and Sommer (339, 340) studied the effect of the composition of butter fat on its susceptibility toward oxidation. They found the stability of a fat toward oxidation bore an inverse relation to the degree of unsaturation of the fat, with linoleic acid content rather than oleic acid the principal governing factor. When cows received grass as a part of their ration the fat became less saturated and more susceptible to oxidation. These workers (338) found that a tallowy flavor and peroxide formation began at about the same time and that considerable loss of color had already occurred.

Sommer (335) reported that trimethylamine was the immediate cause of fishiness in butter. He believed this flavor to be the result of oxidation of the lecithin in the butter. That fishiness is the result of oxidation of the lecithin has been verified by the work of Holm *et al.* (172) and Jensen and Ritter (193), but the steps whereby this oxidation takes place have not been entirely established.

Milk and Cream—As early as 1916 Guthrie (141) had recognized a metallic flavor in cream and his observation had led him to believe that it was caused by factors other than direct contact with metals. He observed further that cream having only a slight metallic flavor yielded buttermilk which was very metallic in flavor after churning in a glass churn. He was unable to establish a relationship between the fatty acids, caprylic, palmitic, stearic, oleic or propionic and the metallic flavor. In 1932 Tracy (363) reported "cappy" or "tallowy" flavor in milk to be the result of oxidation of the milk fat. This view was supported the following year by the report of Kende (198) who found a decrease in iodine number of butter fat when an "oleagenous" or oily flavor developed in the milk. Mohr and Wellm (246) stated that "emery" flavor is similar to but not identical with oily, tallowy, or rancid flavors. They reported that the unknown compound causing emery flavor was soluble in the fat phase and hence carried into the butter. Dahle (66) reported that butter fat was the substance affected when oxidized flavor develops in milk. He found that the iodine number decreased in proportion to the degree of flavor present.

In 1935 Thurston and Barnhart (358) reported an oxidized flavor in the buttermilk from churned sweet cream. This product was known to be high in phospholipids. In the same year Thurston, Brown and Dustman (359) found that oxidized flavor was pronounced in the cream, skim milk, butter and buttermilk, but that only a faint trace of the flavor was found in the butter fat washed by continuous reseparation and dilution with water. When the washed butterfat was redispersed in skim milk no oxidized flavor could be detected. Likewise, they were enable to develop an oxidized flavor in this product by methods ordinarily used to cause the development of this flavor defect. These workers caused a tallowy flavor to develop in butter oil by bubbling oxygen through it at 75° C. When they redispersed this oxidized butter oil by homogenization into the skim milk, a typical tallowy flavor resulted. However, the flavor was unlike the characteristic oxidized flavor of milk. These authors believed that lecithin rather than butterfat was affected when oxidized flavor developed in milk. In a later work (360) they explained the inhibiting effect of agitation of cold milk on the development of oxidized flavor as being the result of partial transfer of lecithin from the fat globule surface to the plasma. They considered this as further evidence that lecithin was the constituent affected. Dahle (65) reported that cream and pure butter oil mixed with the skim milk of certain cows de-

veloped an oxidized flavor, but that the cream often reacted more quickly than the butter oil. He considered this as evidence that the phospholipids may react before the fat itself. The phospholipids of milk are readily susceptible to oxidation.

Brown, Dustman, and Thurston (32) in 12 trials during the winter months of two successive years found no measurable change in the iodine number of milk fat from oxidized and normal milk. They showed by calculation that one would not expect to obtain any difference in the iodine number of milk fat as a result of oxidation of the double bond in oleostearo lecithin because of the relatively small amount of lecithin present.

In a more recent work Swanson and Sommer (347) were unable to find any difference in the iodine number of butterfat from normal and oxidized flavored milk. These investigators criticized the calculation of Brown, Dustman and Thurston on the basis that it had been shown that lecithin contains two oleic acid radicals. However they found from the determination of the iodine number of the phospholipid fraction that the development of oxidized flavor is accompanied by a marked decrease in the iodine number of the phospholipid fraction. They concluded that the development of oxidized flavor in milk, catalyzed by copper, is primarily due to the oxidation of the phospholipid fraction and that the oxidation of the unsaturated fatty acids in this fraction is not complete. The indications were that one molecule of an unsaturated fatty acid, undoubtedly oleic acid, remained unoxidized.

Dahle and Palmer (78) considered spontaneous oxidized flavor, *i.e.*, without copper catalysis, to be due to the oxidation of the phospholipid fraction of the fat globule membrane and the butterfat.

Roland and Trebler (311) studied the effect of fat content on oxidized flavor in milk and cream. They reported that mechanical separation of milk produced a marked decrease in its sensitivity to copper-induced oxidized flavor as evidenced by tests on reconstituted milk made by recombining cream and skim milk. They suggested that the removal of lecithin or related substances by the separator or changes in their distribution between the fat and aqueous phase may be responsible for the decreased sensitivity.

Josephson and Doan (196) reported that they were able to develop a typical oxidized flavor by heating a suspension of pure phospholipids in water in the presence of copper. A protein suspension similarly prepared developed a different flavor when heated in the presence of copper. A suspension of phospholipid and protein combined, oxidized readily without heat or copper but became much more tallowy (oxidized) when heated, treated with copper, or when subjected to both treatments.

In 1936 Greenbank (133) reported that some constituent of milk is readily oxidized since the oxidation occurs at 5° C. in an atmosphere of 2.5 per cent oxygen. He excluded from consideration fat, casein, lactose, and albumen, and stated that if lecithin was the factor involved, as reported by

Thurston, *et al.*, all milks should develop oxidized flavor since they all contain lecithin. Apparently the problem was much more involved than he believed at that time. Greenbank presented a theory in which he visualized the flavored product as an intermediate step in an oxidation reaction, the end product being flavorless. At the present time the literature on oxidized flavor does not reveal cases in which oxidized flavored products have lost their flavor due to continued oxidation.

The present status of the literature indicates that tallowy flavor of butter is probably the result of oxidation of the fat, this oxidation beginning at the surface and probably working toward the center of the product. Likewise, the evidence points to a fishy flavor of butter as being the result of an oxidation process. In this case lecithin is probably the parent substance of trimethylamine, the latter being the immediate cause of fishy flavor. The trend in the literature at the present time seems to point to the phospholipid fraction as the source of oxidized flavors in milk and cream. However, as a result of differences in terminology of flavors many apparently conflicting lines of evidence have been reported.

XIII. METHODS OF PREDICTING AND DETECTING ONSET OF OXIDATION

Holm and Greenbank (166) reported in 1922 that oleic acid exposed to oxygen for some time gave the characteristic tallowy odor and proportionate peroxide and Kreis tests. In a later work (165, 167) they measured the amount of oxygen absorbed by a fat during oxidation and studied acidity, iodine number, iodine liberated from potassium iodide in 24 hours, and the Kreis test as means of detecting rancidity. Of these tests only the Kreis test gave results that detected small differences in the degree of oxidation. Bevis (23) found that aeration caused bleaching, the development of a positive Kreis test, and a decrease in the iodine number. She observed an increase in free fatty acids but this had no relation to the Kreis test.

Holm and Greenbank (168) studied the relation of the Kreis test to oxygen absorption by linoleic and ricinoleic acids. These acids absorbed oxygen and gave a positive Kreis test, the colors developed were less intense than with oleic acid. Linoleic and ricinoleic acids gave but faint tallowy odors even after large amounts of oxygen were absorbed. They (137a) describe an apparatus for determining the oxygen absorption by fats. Nagel and Von Have (257) using an oxygen uptake procedure demonstrated a catalytic effect of copper oxide on drying and non-drying oils. Tschirch and Barben (377) reported that rancid fats gave the Kreis test for deterioration and showed peroxides present. Inichof and Schosldrine (186) reported that a determination of the amount of aldehydes present is the only means of precisely estimating the rancidity of butter. They described a method for their determination.

Davies (81) reported a test for forecasting the deterioration of butter by means of oxidation potentials as determined by methylene blue.

Lucas *et al.* (223) checked the scores of butter against amino nitrogen and total nitrogen, acid number, iodine number, Reichert-Meissl number and the Kreis test. After six months storage each sample was tested for trimethylamine. They found no relationship between these tests and the keeping quality as determined by score except in the case of the Kreis test. Butter with a fishy flavor after storage for six months showed a positive trimethylamine test. Briggs (28) reported that the acid, iodine and peroxide values remained practically unchanged during the induction period. The acid value failed to show a close relation to the absorption of oxygen, there being a distinct lag indicating that the production of acid is a secondary process. He concluded that the acid value was not a satisfactory means of detecting the progress of oxidation. The iodine value was found to decrease nearly in proportion to the absorption of oxygen. He concluded that although the determination of iodine number gives no indication of any changes during the induction period, it does give a fairly satisfactory guide to the progress of later oxidation. The Kreis test was found to be quite sensitive.

Kobert (204) reported that only compounds containing an allyl group or a substituted allyl group were capable of forming red condensation products with phloroglucinol. Ginzberg and Fomina (123) proposed a new constant "oxygen number," for fat investigation. The oxygen number is defined as the number of mg. of oxygen (from $KMnO_4$) required to titrate a fat. It is similar to, but not identical with, the iodine number.

Triebold and Bailey (371) found little or no relationship between the iodine number and the keeping quality of shortening. There was a slight tendency for those samples showing lower iodine numbers to have better keeping quality.

Taufel and Thaler (350) reported a new analytical method for the determination of ketones in rancid fats. Aspegren (12) studied the changes in shortening and oils by heating them in an oven at 145° F. This treatment over a period of 106 days increased the nitrogen content and decreased the iodine number. Taufel (349) and Wheeler (397) have reviewed the tests for fat spoilage. The latter developed a convenient method for the determination of peroxides. This is not satisfactory as a single test in the early stages but after appreciable oxidation has occurred it indicates how far the oxidation has proceeded. Wheeler found a high peroxide value always accompanied by a high Kreis test. Frehden (108) likewise has described a new test for fat spoilage but its sensitivity has not been determined. Ritter (292a) developed a test for copper in butter by use of the peroxide reaction. The copper content of butter is closely associated with keeping quality. Joyner and McIntyre (197) used the oven test as an index to keeping quality of fats. Closely paralleling this is the holding test for butter as reported by Jacobsen (190) and Parsons (273). Under this test the butters are held at room tem-

perature for a short period, whereby the rate of decomposition is greatly accelerated. Ritter and Nussbaumer (301, 304) reported a method for the determination of keeping quality based upon the length of time required for the peroxide number as developed by Wheeler to reach a value between 5 and 10. Beyond this range the value increases very rapidly.

Trout and Sharp (375) found taste a reliable method for the detection of oxidized flavor in milk.

Many chemical tests have been proposed as measures of the rapidity with which oxidation takes place and these have met with varying degrees of success. Among them the Kreis test and the peroxide number, however, appear to be the most sensitive and of greatest value in detecting th onset of oxidation.

XIV. ANTIOXIDANTS

Early Work—The original work on antioxidants was probably inspired by the finding that certain substances accelerated the rate of oxidation of certain materials. Bevis (23) found that oleic acid added to beef fat promoted the development of rancidity. Glycerin had no effect. Fridericia (110) reported that when certain animal fats, such as lard or hydrogenated whale oil, were mixed in rations containing butter as a source of vitamin A the animals suffered from vitamin A deficiency. Greenbank and Holm (137) observed the acceleration of oleic acid on the rate of oxidation of fats. Moureu and Dufraisse (252) studied the catalytic properties of iodine and its compounds on the auto-oxidation of acrolein. In each case an appreciable positive or negative effect was observed, but the nature of the action could not be predicted.

Smith and Wood (332) studied the effect of inhibiting agents in the oxidation of unsaturated organic compounds. Over 100 chemicals were tried using the oxygen absorption method. They classified the retarding agents in order of their effectiveness. These workers expressed two hypotheses: 1. The antioxidant, being basic, combines with the acidic products of oxidation and prevents them from acting as autocatalysts toward oxidation. 2. The triple-bond N atom with 2 partial valences, or elements with free valences, forms intermediate compounds with the easily oxidized ethenoid carbon. This temporary compound controls the rate of reaction for a definite, but limited period of time. Holm, Greenbank, and Deysher (170) presented evidence of the existence of loosely bound oxygen compounds in butter oil. They considered these substances, termed "moloxides," as responsible for oxidation in vacuo. They reported also a powerful retarding action of OH groups in a position analogous to that of the second unsaturated bond in linoleic acid.

Husa and Husa (185) reported that addition of 0.5 per cent of hydroquinone to lard reduced the rate of development of rancidity about 50 per cent. No effect was found from the following compounds on the rate of development of rancidity; salicylic acid, acetyl-salicylic acid, beta-napthol,

liquefied phenol, dl-alanine, pyrogallic acid and resorcinol. Clark (48) found that from 0.5 to 1.0 per cent of phenyl-a-naphthylamine added to such oils or waxes as those used in electric insulation prevented oxidation. Matill and Crawford (236) suggest that the mere presence of double bonds is of less moment for the process of oxidation than is that of substances which initially either accelerate or retard the reaction. The sterols of corn oil were found to greatly prolong the induction period of lard, but acetylated sterols reduced the induction period. Moureu *et al.* (253) prefer the use of the term "antioxygen" to antioxidant because they claim that an article, which is to be protected against oxygen, after having been subjected to the action of air, will need a greater proportion of antioxygen to make up for that which will be destroyed by the peroxides already formed.

Hilditch and Paul (159) reported basic compounds in linseed oil and cottonseed meal. The antioxygenic activity was suppressed by treatment with anhydrous HCl and partly restored by neutralization with sodium methoxide. The identity of the basic compound was not determined, but they believed it to be a basic oxygen rather than a basic nitrogen compound. Matill (235) made a review of the antioxidants and autoxidants of fat. After studying a large number of compounds his observations indicate that antioxygenic capacity of phenols resides in two hydroxyl groups in either the ortho or para configuration; when these were in the meta position the compound was inactive. The hydroxyls were ineffective unless attached directly to the ring; the fully hydroxylated inosite is inactive. In the naphthols one hydroxyl group is sufficient and in keeping with its accepted behavior, a-naphthol has the character of an ortho compound and is much more effective as an antioxidant than b-naphthol; quinone is effective and b-naphthoquinone is even more so but the alpha form is inactive. Stiepel (341) also found naphthol effective. Matill discusses these facts in relation to the more recent theories of the electronic structure of the benzene ring and autoxidation. A number of sterols of animal origin and sitosterol from wheat, corn, and lettuce were all inactive. The existence of pro- and antioxygenic substances among the non-saponifiable constituents of natural fats and oils suggests that some of these may be concerned with the physiological action of the fat-soluble vitamins. Baumann and Steenbock (19) reported that pure vitamin A and pure carotene were destroyed by ultra-violet light in one-half hour whereas the crude product was stable during exposure for five hours. Briggs (27) reported antioxygenic effect for curd in butter whereas humidity, glycerol, triolein, lactose, iodine, potassium iodide and pasteurization had little or no effect.

Monalgalm and Schmidt (247) reported that vitamin A was found to completely inhibit oxygen uptake of linoleic acid for some hours but that it loses inhibiting power when the vitamin is destroyed by oxidation. Likewise, the presence of carotene was shown to strongly inhibit oxidation during the first

few hours during which time it becomes bleached (presumably oxidized), and then it increases the oxygen uptake. Koenig (206) found that carotenoid pigments inhibit rancidity in fats and Greenbank and Holm (139) reported carotene an antioxidant for acids but not for glycerides. Newton (259) reported that carotenoid pigments act as antioxidants and that these antioxident properties carried over into finished bakery products. In contrast to this Bradway and Matill (26) and Olcovich and Matill (265) report that carotene is pro-oxygenic but that crude carotene may be antioxygenic due to an associated inhibitor. In the latter work these investigators found that carotene in autoxidizable fat shortened the induction period and concluded that carotene is a pro-oxidant.

Guillaudeu (140) reported that cyanamide compounds added to soap chips inhibit oxidation. Murrill (256) reported phenyl phenolate to have antioxidant properties. Yamaguchi (410) found antioxidant properties for copper oleate and manganese linoleate. Palit (269) reported that proteins and carbohydrates retard fat oxidation. Roller (312) stated that not all samples of wheat germ oil act as antioxidants for fat, oils, and food rations. The activity was not dependent upon the amount of lecithin, sitosterol, unsaponifiable matter or free from fatty acids present. He believed the activity to be due to free OH groups either on the glycerol or on the ricinoleic acid which the oil was thought to contain. Salzberg (320) reported antioxidant activity for catechol monodedecyl ether or other suitable phenols of the benzene series having at least one alkoxy group in position o- or p- to a hydroxyl group and containing 12 carbon atoms in such alkoxy group. Greenbank (132) found the treatment of oils or fats with a small proportion of an unsaturated polybasic aliphatic acid such as maleic, aconitic, fumaric, citraconic or itaconic acid or derivatives such as maleic anhydride or ethyl or sodium maleate, to be effective in inhibiting oxidation. In a later work Greenbank and Holm (139) found hydroquinone, phthalic acid and maleic acid good antioxidants. Maleic acid was the best of the three. Olcott (261) found pyrogallol, hydroquinone, pyrocatechol, hydroxyhydroquinone and apionol excellent antioxidants. The 1, 3, and 1, 8 naphthalenediols were effective whereas the 1, 4 derivative was inactive. The esterification and alkylation of one or more of the hydroxyl groups destroyed or greatly reduced antioxygenic activity. Side chains of the benzene nucleus reduce the activity of hydroquinone. The quinones possess slight activity and 1, 4 cyclohexanediol and saligenin were inactive. Maleic, tartaric and citric acids were inactive.

Coe and LeClerc (55) found maleic and phthalic acids, hydroquinone, pyrogallol, pyrocatechol and guaiacol to act as antioxidants. Lea (217) reported Na-maleate, NH_4-lactate, Na-tartrate, Na-glycolate, and Na-lactate as moderate antioxidants and glycine, asparagine, Na-citrate, and Na-malonate as powerful antioxidants.

In 1935 Evans (100) found that when mixed with cotton seed oil, lecithin (probably a mixture of lectithin and cephalin) greatly retarded peroxide formation. It was found more effective than diphenylguanidine, hydroquinone and KCN. He found the antioxidant property of lecithin destroyed by heating to 65° C. Sitosterol was also shown to inhibit peroxide formation. He explained the antioxidant properties of palm kernel oil on the basis of its sitosterol content. Holmes *et al.* (173) reported hydroquinone and lecithin as antioxidants for vitamin A in halibut liver and cod liver oils. Lecithin was found more effective than hydroquinone at 96° C. Koenig (206) found lecithin to inhibit the development of rancidity of butter. Olcott and Matill (264) reported that purified lecithin was not an antioxidant but that purified cephalin was. Ritter and Nussbaumer (303) found lecithin and particularly cephalin obtained from plant lecithin, to have strong antioxidizing effect.

Sabalitschka and Bohm (317) reported that the oxidation of organic substances readily liable to atmospheric oxidation is prevented by incorporation of substances of the formula RCOOR'N (R″)R′ ′, where R is hydrogen, alkyl, alkylene or aryl, which may be substituted by OH, hydroxyalkyl, an alkyl or NH_2, R′ is alkylene with not more than 4 carbon atoms, R″ is alkylene with not more than 3 carbon atoms and R′ ′ is hydrogen or alkyl with not more than 3 carbon atoms. Hinsberg and Nowakowski (162) found that many porphyrins inhibit autoxidation of linseed oil. The effect was related to the number of carboxyl groups in the molecule. Kochling and Taufel (205) studied the role of maltol in fat spoilage. It was found to exert antioxidant action only under highly acid conditions. French, Olcott, and Matill (109) found a prolongation of the induction period by fractions of unsaponifiable lipids of wheat germ oil and palm oil.

Hamilton and Olcott (149) reported that from experiments with antioxidants phenolic inhibitors and inhibitols cause no change subsequent to the end of the induction period, but exert their effect solely by inhibiting the formation of the initial monoxide and are then entirely destroyed before the start of rapid oxidation. Olcott and Matill (263) studied antioxidants and autoxidation of fats. They classified the inhibitors into three groups: 1. acid type, 2. inhibitol and hydroquinone, and 3. other phenolic inhibitors. In general any type one inhibitor used with any type 2 or 3 compound prolonged the induction period to a much greater extent than would be expected from a summation of the effects of each used alone.

Olcott and Emerson (262) found the tocopherols to have antioxidant properties in lard. Maveety (238) found the residue from the distillation of spice oils to have antioxigenic properties. The substances were not isolated. Takahashi and Masuda (348) found the phenol compounds in incompletely burned oak smoke to have antioxygenic properties. Ritter and Nussbaumer (301) reported antioxidative properties for hydroquinone.

Coun and Asnis (58) found that dusting freshly prepared potato chips with oat flour retarded peroxide formation. Likewise treating parchment paper wrapper with oat flour definitely retarded oxidation of lard. Lowen, Anderson and Harrison (221) found oat flour to retard the initial peroxide formation in halibut and salmon oils.

Butter and Ice Cream—Koenig (206, 206a) found that parchment paper wrapper treated with oat flour and a hexane extract of oats (avenol) used in butter, had a protective action against the development of rancidity. Dahle and Josephson (74) found that avenex-treated parchment paper was beneficial in retarding flavor defects at 45° F. but of little benefit as long as butter remained in storage at −15° F. In another study they found water extract of avenex improved the keeping quality of butter without injuring the flavor or incorporating sediment into the butter. Dahle (68) reported that oat flour in butter delayed not only the development of tallowiness but also such flavors as stale and cheesy. He suggested that these flavors may be of an oxidative nature. Ritter and Nussbaumer (303) found avenex to have antioxidant properties as did Corbett and Tracy (56) who reported a beneficial effect on the development of oxidized flavors in butter. The use of avenized parchment paper retarded surface flavors and improved keeping quality.

Mueller and Mack (255) found that 0.25 per cent of oat flour in ice cream had antioxidative properties and delayed the development of off-flavors. They found 0.5 per cent still more effective. Brown (36) likewise found 0.5 per cent effective. Weckel (389) recommended the use of not more than 0.3 per cent avenex for vanilla ice cream and up to 0.5 per cent for strawberry ice cream. Dahle and Josephson (72, 73) reported 0.3 per cent not quite sufficient to completely inhibit oxidized flavor development in strawberry ice cream beyond 4 weeks time. However, 0.5 and 0.7 per cent proved an effective antioxidant. Maack and Tracy (224) and Burke and Newman (42) found 0.5 per cent of avenex an ample antioxidant for preserving the fresh flavor in ice cream.

Bird, Ross, Iverson, Ause and Willingham (24) reported that the higher the iron content of ice cream the less the tendency for it to develop oxidized flavors. They believed the iron probably combined in the ferrous form and served as an antioxidant.

Milk and Cream—Ritter (291) obtained antioxidative properties from hydroquinone, metol and ascorbic acid when used for tallowy flavor in milk. Ritter and Christen (296) reported from 5 to 7 per cent of hydroquinone in a bacteria culture which was known to prevent a tallowy flavor in milk. Chilson (47) found that ascorbic acid and hydroquinone when added directly to milk prevented oxidized flavor development. Greenbank (133) also reported the beneficial effect of added ascorbic acid on milk. Dahle and Palmer (78) and Dahle (67) in addition to confirming these findings on

ascorbic acid, substantiated the effect of hydroquinone and added oat flour as antioxidants for milk. Maleic acid and carotene, in the quantities used, were found to be ineffective. Guthrie, Hand and Sharp (143) found that the use of paper bottles markedly decreased the effect of sunlight on the oxidation of ascorbic acid and on the production of off-flavors. Garrett (111) found that oat flour exhibited definite antioxidative properties in retarding the development of oxidized flavor in milk as induced by copper contamination or exposure to sunlight. Weckel (389) recommended the use of 2 per cent avenex for controlling stale flavor in storage cream.

Deco (87) reported that boiling milk in large lots for an hour or more in contact with air, as practiced in some Belgian hospitals, destroyed 40 to 65 per cent of the vitamin A and 20 to 25 per cent of the carotene. Both of these substances have been reported as having certain antioxidative properties.

Anderson (4) reported that the use of pancreatic enzyme in milk prevented the development of oxidized flavor whether the difficulty is due to metal contamination or to naturally high susceptibility of the milk. He believed the pancreatic enzyme to be specific for the prevention of the development of oxidized flavor and that it acted as an antioxidant.

Apparently there are a number of antioxidants which will prevent the development of oxidized flavor in milk and dairy products. The use of these in milk is largely restricted because of laws in most states which prohibit the addition of any non-milk ingredient to milk.

SUMMARY

Of all the factors concerned in bringing about oxidative changes in dairy products metallic contamination, particularly by copper, is at present the most important. The control of copper contamination in processing becomes increasingly more important as the sanitary quality of the products is improved. However, not all milk must have copper contamination to develop an oxidized flavor. Fortunately, the percentage of milk which develops oxidized flavor spontaneously is relatively small and when this milk is mixed with normal milk it remains normal in flavor. For this reason it is not of as great commercial importance as is milk susceptible to metal-induced oxidized flavor.

Oxidized flavor in milk has been shown to be associated with milk of low bacterial count. The growth of bacteria in the milk, either by using up the oxygen or by reduction of the potential, render milk non-susceptible even in the presence of copper.

Oxidized flavor in milk was originally believed to be the result of oxidation of the fat catalyzed by copper and brought about through the action of an enzyme. The recent trend in literature points to the phospholipid fraction as the source of the flavor and recent work on cooked flavor questions seriously the action of an enzyme in bringing about the defect.

Grass feeding has been shown to reduce the susceptibility of milk to oxidized flavor even though the milk fat is made more susceptible to ordinary chemical oxidation. This is explained on the basis of reducing substances in the feed or in the milk, or in both. Various investigations have shown that ascorbic acid and carotene in the feed tend to reduce the susceptibility of the milk. Also a number of antioxidants have been demonstrated to have protective qualities. The mechanism whereby an oxidized flavor develops has not been completely demonstrated nor has the mechanism whereby the various factors exert their effects.

Tallowy flavor in butter appears to be the result of metal-induced oxidation of the fat, the point of attack probably being the double bonds in the oleic and linoleic acid radicles.

Light and oxygen have been demonstrated to be important factors favoring oxidative changes. Oxidation will take place in the absence of light but the rate of reaction is slow. The source of oxygen may be either the free or the combined form.

Both strong acid and alkaline reactions have been shown to favor oxidative changes. Over-neutralization is known to favor oxidative changes while butter made from high acid cream in the presence of copper contamination and salt is prone to become fishy upon storage.

Both salt and moisture appear to play a role in the development of oxidative changes but they are of minor importance when compared to metallic contamination.

Temperature is important only as a regulator of the rate of oxidative change. As the temperature increases the rate of oxidative change increases, all other factors being constant. Low temperature storage favors a slow rate of oxidative change.

Development of tallowy or oxidized flavor in ice cream is undoubtedly an oxidative change. In this product, however, we have the possibility that the oxidative changes may affect either the phospholipid fraction or the butterfat or both. The present work points toward fat as the substance oxidized. If the present trend of research on oxidized flavor of milk continues, a reexamination of tallowy flavor in ice cream would seem desirable.

The elimination of copper contamination is one of the major problems confronting the dairy industry today as the flavor problems resulting from chemical reactions have a copper history in the vast majority of cases. If these problems are to be eliminated by removal of the cause, it will be necessary for copper to be eliminated from all surfaces with which milk comes in contact because of the extremely small amount of copper required to develop the flavor in many cases.

The authors wish to express their appreciation to Dr. R. B. Dustman, Department of Agricultural Chemistry, West Virginia Agricultural Experiment Station, for advice and criticism in the preparation of this paper.

REFERENCES

(1) AIKINS, G. A., AND FAY, A. C. J. Agr. Res., 44: 85–95. 1932.
(2) ANDERSON, A. K., AND TRIEBOLD, H. O. J. DAIRY SC., 15: 469. 1932.
(3) ANDERSON, E. O. Intern. Assoc. Milk Dealers, Lab. Sect., 153. 1937.
(4) ANDERSON, E. O. Milk Dealer, 29: 32. 1939.
(5) ANDERSON, E. O., DOWD, L. R., AND STUEWER, C. A. Food Res., 2: 143–150. 1937.
(6) ANDERSON, J. A. Intern. Assoc. Milk Dealers, Lab. Sect., 117. 1936.
(7) ANDERSON, J. A. Milk Dealer, 26: 60. 1936.
(8) ANDERSON, J. A. Intern. Assoc. Milk Sanitarians, 223. 1936.
(9) ANDERSON, J. A., HARDENBERGH, J. G., AND WILSON, L. T. J. DAIRY SC., 19: 483. 1936.
(10) ANDERSON, J. A., WILSON, L. T., AND HARDENBERGH, J. G. Intern. Assoc. Milk Dealers, Lab. Sect., 177. 1937.
(11) ANONYMOUS. Molkerei-Zeitung, 25: 1095. 1911.
(12) ASPEGREN, H. Oil and Soap, 9: 108. 1932.
(13) BARKWORTH, H. Dairy Ind., 3: 7–8. 1938.
(14) BARNICOAT, C. R. New Zealand J. Sc. Tech., 19: 546–551. 1938.
(15) BARNICOAT, C. R. New Zealand J. Sc. Tech., 19: 552–556. 1938.
(16) BARNICOAT, C. R. New Zealand J. Sc. Tech., 19: 556–562. 1938.
(17) BARNICOAT, C. R. New Zealand J. Sc. Tech., 19: 562–572. 1938.
(18) BARTLETT, S., COTTON, A. G., HENRY, K. M., AND KON, S. K. J. Dairy Res., 9: 273–309. 1938.
(19) BAUMANN, C. A., AND STEENBOCK, H. Wis. Agr. Exp. Sta. Bull., 420: 77. 1931.
(20) BAUMANN, C. A., AND STEENBOCK, H. J. Biol. Chem., 101: 547. 1933.
(21) BAUMANN, C. A., STEENBOCK, H., BEESON, W. M., AND RUPEL, I. W. J. Biol. Chem., 105: 167–176. 1934.
(22) BECK, G. H., WHITNAH, C. H., AND MARTIN, W. H. J. DAIRY SC., 22: 17. 1939.
(23) BEVIS, J. F. J. Soc. Chem. Ind., 42: 417. 1923.
(24) BIRD, E. W., ROSS, O. E., IVERSON, C. A., AUSE, O. R., AND WILLINGHAM, J. J. Iowa Agr. Exp. Sta. Res. Bull., 230: 291. 1938.
(25) BOOTH, R. G., KON, S. K., DANN, W. J., AND MOORE, T. Biochem. J., 27: 1189–1196. 1933.
(26) BRADWAY, E. M., AND MATILL, H. A. J. Amer. Chem. Soc., 56: 2405. 1934.
(27) BRIGGS, L. H. J. Dairy Res., 3: 61. 1931.
(28) BRIGGS, L. H. J. Dairy Res., 3: 70. 1931.
(29) BROCHOT, F. Le Lait, 18: 23–43. 1938.
(30) BROWN, W. C., THURSTON, L. M., AND DUSTMAN, R. B. J. DAIRY SC., 19: 753. 1936.
(31) BROWN, W. C., THURSTON, L. M., AND DUSTMAN, R. B. J. DAIRY SC., 20: 133. 1937.
(32) BROWN, W. C., DUSTMAN, R. B., AND THURSTON, L. M. J. DAIRY SC., 20: 604. 1937.
(33) BROWN, W. C., AND DUSTMAN, R. B. J. DAIRY SC., 21: 144. 1938.
(34) BROWN, W. C., AND DUSTMAN, R. B. J. DAIRY SC., 22: 31. 1939.
(35) BROWN, W. C., VANLANDINGHAM, A. H., AND WEAKLEY, JR., C. E. J. DAIRY SC., 22: 349. 1939.
(36) BROWN, W. H. Ice Cream Field, 31: 31. 1937.
(37) BROWN, W. H., TRACY, P. H., AND PRUCHA, M. J. J. DAIRY SC., 19: 488. 1936.
(38) BROWNE, C. A. J. Amer. Chem. Soc., 21: 975. 1899.
(39) BROWNE, C. A. Ind. and Eng. Chem., 17: 44–47. 1925.
(40) BRUECKNER, H. J., AND GUTHRIE, E. S. Proc. Int. Assoc. Milk Dealers, Lab. Sect., 3. 1934.

(41) BUHL, S. C. Maelkeritid, 16: 709–710. 1903. (Original not seen.) Exp. Sta. Rec., 15: 1117. 1903–04.
(42) BURKE, A. D., AND NEWMAN, R. M. Ice Cream Rev., Feb., 50. 1939.
(43) BURR, A. Illus. Landw. Ztg., 27: 274–275. 1907. (Original not seen.) Chem. Abs., 1: 1879. 1907.
(44) BURUIANA, L. Biochem. J., 31: 1452. 1937.
(45) BUTTON, F. C. N. J. Agr. Exp. Sta. Ext. Serv. Bull. 110. 1933.
(46) CANZONERI, F., AND BIANCHINI, G. Ann. Chim. Appl., 1: 24–32. 1914. (Original not seen.) Chem. Abs., 8: 2201. 1914.
(47) CHILSON, W. H. Milk Plant Mo., 24: 34. 1935.
(48) CLARK, F. M. Brit., 351: 171. 1929. (Original not seen.) Chem. Abs., 26: 3130. 1929.
(49) CLAVEL, J. Teintex, 3: 521. 1938.
(50) COE, M. R. Science, 75: 585. 1932.
(51) COE, M. R. U. S. Dept. Agr. Yr. Book, 306–308. 1934.
(52) COE, M. R. Cereal Chem., 11: 241–258. 1934.
(53) COE, M. R., AND LECLERC, J. A. Cereal Chem., 9: 519–522. 1932.
(54) COE, M. R., AND LECLERC, J. A. Ind. and Eng. Chem., 26: 245–248. 1934.
(55) COE, M. R., AND LECLERC, J. A. Oil and Soap, 12: 231–233. 1935.
(56) CORBETT, W. J., AND TRACY, P. H. Nat. Butter and Cheese J., 28: 10–14. 1937.
(57) CORBETT, W. J., AND TRACY, P. H. J. DAIRY SC., 23: 209. 1940.
(58) COUN, R. C., AND ASNIS, R. E. Ind. and Eng. Chem., 29: 951. 1937.
(59) COUTTS, F. J. H. N. S. 116, Food Reports, No. 24. 1920. (As reviewed by Dahle and Palmer, J. DAIRY SC., 7: 40. 1924.
(60) CREWS, F. W. Nat. Butter and Cheese J., 29: 18–19. 1938.
(61) CSISZAR, J. Osterr. Milchwirtschaft Ztg., 42: 41–44. 1935. (Original not seen.) Chem. Abs., 29: 3413. 1935.
(62) DAHLBERG, A. C., AND CARPENTER, D. C. J. DAIRY SC., 19: 491. 1936.
(63) DAHLBERG, A. C., AND CARPENTER, D. C. J. DAIRY SC., 19: 541. 1936.
(64) DAHLE, C. D. Penna. Agr. Exp. Sta. Bull., 320: 22. 1935. (Ann. Rept.)
(65) DAHLE, C. D. Penna. Agr. Exp. Sta. Bull., 336: 28. 1936. (Ann. Rept.)
(66) DAHLE, C. D. Ice Cream Field, 28: 6. 1936.
(67) DAHLE, C. D. Milk Dealer, 27: 68. 1938.
(68) DAHLE, C. D. Nat. Butter and Cheese J., 29: 8. 1938.
(69) DAHLE, C. D., AND CARSON, R. B. Penna. Agr. Exp. Sta. Bull., 293: 19. 1933. (Ann. Rept.)
(70) DAHLE, C. D., AND FOLKERS, E. C. Ice Cream Rev., 16: 31. 1932.
(71) DAHLE, C. D., AND FOLKERS, E. C. J. DAIRY SC., 16: 529–547. 1933.
(72) DAHLE, C. D., AND JOSEPHSON, D. V. Ice Cream Field, 31: 15. 1937.
(73) DAHLE, C. D., AND JOSEPHSON, D. V. Ice Cream Rev., 20: 31. 1937.
(74) DAHLE, C. D., AND JOSEPHSON, D. V. Nat. Butter and Cheese J., 28: 6. 1937.
(75) DAHLE, C. D., AND JOSEPHSON, D. V. Nat. Butter and Cheese J., 28: 18. 1937.
(76) DAHLE, C. D., AND PALMER, L. S. J. DAIRY SC., 7: 40. 1924.
(77) DAHLE, C. D., AND PALMER, L. S. J. DAIRY SC., 7: 141. 1924.
(78) DAHLE, C. D., AND PALMER, L. S. Penna. Agr. Expt. Sta. Bull., 347. 1937.
(79) DAVIS, J. G. J. Dairy Res., 3: 241–253. 1932.
(80) DAVIS, R. N. J. DAIRY SC., 22: 3, 179. 1939.
(81) DAVIES, W. L. World's Butter Rev., 2: 9, 16. 1928.
(82) DAVIES, W. L. Oil and Fat Ind., 7: 427, 453. 1930.
(83) DAVIES, W. L. Milk Ind., 13: 55–57. 1933.
(84) DAVIES, W. L. J. Dairy Res., 4: 255–264. 1933.
(85) DAVIES, W. L. J. Soc. Chem. Ind., 53: 148. 1934.

(86) Dean, K. H., and Hilditch, T. P. Biochem. J., 27: 889. 1933.
(87) Deco, M. Compt. Rend. Soc. Biol., 130: 819–821. 1939. (Original not seen.) Chem. Abs., 33: 4687. 1939.
(88) Digeser, A. Molkerei-Ztg. (Hildesheim), 53: 407–410. 1939. (Original not seen.) Chem. Abs., 33: 5077. 1939.
(89) Doan, F. J. Milk Plant Mo., 25: 59. 1935.
(90) Doan, F. J., and Myers, C. H. Milk Dealer, 26: 1, 76. 1936.
(91) Donauer, M. Ice Cream Rev., 5: 7, 78–84. 1922.
(92) Dyer, D. C. J. Agr. Res., 6: 927. 1916.
(93) Echave, D. Rev. Farm (Buenos Aires), 78: 337–341. 1936. (Original not seen.) Chem. Abs., 31: 766. 1937.
(94) Ellenberger, H. B., and White, H. L. Vt. Agr. Exp. Sta. Bull. 299. 1929.
(95) Ellington, E. V. Wash. Agr. Expt. Sta. 45th Ann. Rept. 1935.
(96) Ellis, G. W. Biochem. J., 26: 791 1932.
(97) Emery, J. A., and Henley, R. R. J. Ind. and Eng. Chem., 14: 937. 1922.
(98) Esselen, W. B. Food Res., 4: 4, 329. 1939.
(99) Esselen, W. B., and Fuller, J. E. J. Bact., 37: 501–521. 1939.
(100) Evans, E. I. Ind. and Eng. Chem., 27: 329. 1935.
(101) Fang, W. Y., and Cruess, W. V. Plant Physiol., 4: 537–541. 1929.
(102) Fay, A. C., and Aikins, G. A. J. Agr. Res., 44: 1, 71–83. 1932.
(103) Fierz-David, H. E. Ztschr. Angew. Chem., 38: 6–8. 1925. (Original not seen.) Chem. Abs., 19: 1503. 1925.
(104) Fink, C. G., and Rohrman, F. A. J. Dairy Sc., 15: 73–86. 1932.
(105) Flake, J. C. Amer. Produce Rev., 88: 11, 290. 1939.
(106) Flake, J. C., Weckel, K. G., and Jackson, H. C. J. Dairy Sc., 22: 153. 1939.
(107) Frazier, W. C. J. Dairy Sc., 11: 375. 1928.
(108) Frehden, O. Mikrochim Acta, 2: 214–217. 1937. (Original not seen.) Chem. Abs., 32: 1125. 1937.
(109) French, R. B., Olcott, H. S., and Matill, H. A. Ind. and Eng. Chem., 27: 724–728. 1935.
(110) Fridericia, A. S. J. Biol. Chem., 62: 471. 1924.
(111) Garrett. O. F. Milk Plant Mo., 29: 40. 1940.
(112) Garrett, O. F., Arnold, R. B., and Hartman, G. H. J. Dairy Sc., 23: 47. 1940.
(113) Garrett, O. F., and Bender, C. B. Milk Plant Mo., 29: 23. 1940.
(114) Garrett, O. F., and Overman, O. R. Le Lait, 12: 81–88. 1932.
(115) Garrett, O. F., Tucker, H. H., and Button, F. C. J. Dairy Sc., 21: 121. 1938.
(116) Gaul, L. E., and Staud, A. H. Cert. Milk, March, p. 3. 1935.
(117) Gebhardt, H. T., and Sommer, H. H. Ind. and Eng. Chem., Anal. Ed., 3: 414–418. 1931.
(118) Gebhardt, H. T., and Sommer, H. H. J. Dairy Sc., 14: 416–445. 1931.
(119) Gebhardt, H. T., and Sommer, H. H. J. Dairy Sc., 15: 42–61. 1932.
(120) Genin, G. Le Lait, 15: 159. 1935.
(121) Genin, G. Le Lait, 17: 368. 1937.
(122) Gilchrist, T. S. Can. Dairy and Ice Cream J., 17: 61–63. 1938.
(123) Ginzberg, A. S., and Fomina, G. K. J. Applied Chem. (U.S.S.R.), 5: 221. 1932. (Original not seen.) Chem. Abs., 26: 4971. 1932.
(124) Goard, A. K., and Rideal, E. K. Proc. Roy. Soc. London, Series A, 105: 148. 1924. (Original not seen.) Smythe, J. Biol. Chem., 90: 251. 1931.
(125) Golding, J., and Feilman, E. J. Soc. Chem. Ind., 24: 1285. 1905.
(126) Gondos, M. A. Le Lait, 14: 25. 1934.
(127) Gould, I. A., Jr., and Sommer, H. H. Mich. State Tech. Bull. 164. 1939.
(128) Gould, I. A. J. Dairy Sc., 23: 37. 1940.

(129) GOULD, I. A. J. DAIRY SC., 22: 1017. 1939.
(130) GRANT, F. M. Intern. Assoc. Milk Sanitarians, 9. 1936.
(131) GRAY, C. E., AND MCKAY, G. L. U.S.D.A., Bur. of An. Ind. Bull. 84. 1906.
(132) GREENBANK, G. R. U. S. Patent 1, 898, 363. 1933. (Original not seen.) Chem. Abs., 27: 2833. 1933.
(133) GREENBANK, G. R. Inter. Assoc. Milk Dealers, Lab. Sect., 101. 1936.
(134) GREENBANK, G. R. Oil and Soap, 13: 140–141. 1936.
(135) GREENBANK, G. R. J. DAIRY SC., 21: 144. 1938.
(136) GREENBANK, G. R. J. DAIRY SC., 21: 143. 1938.
(137) GREENBANK, G. R., AND HOLM, G. E. Ind. and Eng. Chem., 16: 598. 1924.
(137a) GREENBANK, G. R., AND HOLM, G. E. Ind. and Eng. Chem., 17: 625. 1925.
(138) GREENBANK, G. R., AND HOLM, G. E. Ind. and Eng. Chem., 25: 167. 1933.
(139) GREENBANK, G. R., AND HOLM, G. E. Ind. and Eng. Chem., 26: 243. 1934.
(140) GUILLAUDEU, A. U. S. Patent 1, 845, 646. 1932. (Original not seen.) Chem. Abs., 26: 2336. 1932.
(141) GUTHRIE, E. S. N. Y. Agr. Exp. Sta. Bull. 373. 1916.
(142) GUTHRIE, E. S., AND BRUECKNER, H. J. N. Y. Agr. Exp. Sta. Bull. 606. 1934.
(143) GUTHRIE, E. S., HAND, D. B., AND SHARP, P. F. Milk Plant Mo., 28: 26–28. 1939.
(144) GUTHRIE, E. S., AND ROADHOUSE, C. L. New York Prod. Rev. and Amer. Cry., 9: 416. 1929.
(145) GUTHRIE, E. S., ROADHOUSE, C. L., AND RICHARDSON, G. A. Hilgardia, 5: 226. 1931.
(146) GUTHRIE, E. S., SCHEIB, B. J., AND STARK, C. N. J. DAIRY SC., 19: 267. 1936.
(147) HAGLUND, E., PLANTON, B., WALLER, E., AND SODERBERG, E. Medd. Centr. 347, 37, 25. 1929. (Original not seen.) Chem. Abs., 32: 4509. 1929.
(148) HAGLUND, E., AND WALKER, E. Medd. Centr. 261, 16, 1924. (Original not seen.) Exp. Sta. Rec., 53: 882. 1924.
(149) HAMILTON, L. A., AND OLCOTT, H. S. Oil and Soap, 13: 127. 1936.
(150) HAMMER, B. W., AND CORDES, W. A. Iowa Agr. Exp. Sta. Res. Bull. 64. 1920.
(151) HAND, D. B., GUTHRIE, E. S., AND SHARP, P. F. Science, 87: 439–441. 1938.
(152) HANUS, J. Listy. Chem., 23, 26, 67. 1899. (Original not seen.) Exp. Sta. Rec., 11: 584. 1899–1900.
(153) HENDERSON, J. L. Milk Plant Mo., 28: 26. 1939.
(154) HENDERSON, J. L., AND ROADHOUSE, C. L. J. DAIRY SC., 17: 321–330. 1934.
(155) HENDERSON, J. L., AND ROADHOUSE, C. L. J. DAIRY SC., 23: 215. 1940.
(156) HENING, J. C., AND DAHLBERG, A. C. J. DAIRY SC., 21: 109. 1938.
(157) HENING, J. C., AND DAHLBERG, A. C. J. DAIRY SC., 21: 345–352. 1938.
(158) HERRINGTON, B. L., AND BRERETON, J. G. J. DAIRY SC., 20: 197. 1937.
(159) HILDITCH, T. P., AND PAUL, S. J. Soc. Chem. Ind., 58: 21–24. 1931.
(160) HILL, O. J., AND PALMER, L. S. J. DAIRY SC., 21: 529–544. 1938.
(161) HILTON, J. H., HAUGE, S. M., AND WILBUR, J. W. J. DAIRY SC., 16: 355–361. 1933.
(162) HINSBERG, K., AND NOWAKOWSKI, H. Biochem. Z., 300: 313–324. 1939.
(163) HODGSON, R. E., KNOTT, J. C., MURER, H. K., AND GRAVES, R. R. J. Agr. Res., 57: 513–529. 1938.
(164) HOFT, DR. Milchwirtschaftliches Centralblatt., 5: 250. 1909. (Original not seen.)
(165) HOLM, G. E. Proc. World's Dairy Congress, p. 1253. 1923.
(166) HOLM, G. E., AND GREENBANK, G. R. Proc. Soc. Exp. Biol. and Med., 20: 1176. 1922.
(167) HOLM, G. E., AND GREENBANK, G. R. Ind. and Eng. Chem., 15: 1051. 1923.
(168) HOLM, G. E., AND GREENBANK, G. R. Ind. and Eng. Chem., 16: 518. 1924.
(169) HOLM, G. E., GREENBANK, G. R., AND DEYSHER, E. F. J. DAIRY SC., 8: 512. 1925.

(170) HOLM, G. E., GREENBANK, G. R., AND DEYSHER, E. F. Ind. and Eng. Chem., 19: 156. 1927.
(171) HOLM, G. E., WRIGHT, P. A., AND GREENBANK, G. R. J. DAIRY SC., 10: 33. 1927.
(172) HOLM, G. E., WRIGHT, P. A., WHITE, W., AND DEYSHER, E. F. J. DAIRY SC., 21: 385. 1938.
(173) HOLMES, H. N., CORBETT, R. E., AND HARTZLER, E. R. Ind. and Eng. Chem., 28: 133. 1936.
(174) HOPKINS, F. G. Biochem. J., 14: 724. 1920.
(175) HOPKINS, F. G. Compt. Rend. Trav. Lab. Carlsberg, Ser. Chim., 22: 226–234. 1938. (Original not seen.) Chem. Abs., 32: 6265. 1938.
(176) HORRALL, B. E., AND EPPLE, W. F. J. DAIRY SC., 23: 53. 1940.
(177) HUNZIKER, O. F. Condensed Milk and Milk Powder, Ed. 3, p. 251. 1920.
(178) HUNZIKER, O. F. Butter Industry, p. 484. 1920.
(179) HUNZIKER, O. F. J. DAIRY SC., 7: 484. 1924.
(180) HUNZIKER, O. F. Cry. and Milk Plant Mo., 14: 47. 1925.
(181) HUNZIKER, O. F., CORDES, W. A., AND NISSEN, B. H. J. DAIRY SC., 12: 140. 1929.
(182) HUNZIKER, O. F., CORDES, W. A., AND NISSEN, B. H. J. DAIRY SC., 12: 252. 1929.
(183) HUNZIKER, O. F., AND HOSMAN, D. F. J. DAIRY SC., 1: 320. 1917.
(184) HUNZIKER, O. F., MILLS, H. C., AND SPITZER, G. Ind. Exp. Sta. Bull. 159. 1912.
(185) HUSA, W. J., AND HUSA, L. M. J. Amer. Pharm. Assn., 17: 243. 1928.
(185a) HYLAND, J., AND LLOYD, L. L. J. Soc. Chem. Ind., 34: 62. 1915.
(186) INICHOF, G. S., AND SCHOSLDRINE, F. Bul. Russe, 64: 159. 1928. (Original not seen.)
(187) IVERSON, C. A. Intern. Assoc. Ice Cream Mfrs., Prod. and Lab. Council, 7–19. 1937.
(188) IVERSON, C. A. Ice Cream Trade J., 33: 24. 1937.
(189) JACKSON, C. J. J. Dairy Res., 7: 31. 1936.
(190) JACOBSEN, D. H. S. Dak. Agr. Exp. Sta. Bull. 308. 1937.
(191) JACOBSEN, D. H. J. DAIRY SC., 21: 187–193. 1938.
(192) JENSEN, J. Landw. Jahrb. der Schweiz. 1901. (Original not seen.)
(193) JENSEN, J., AND RITTER, W. Le Lait, 18: 758–773. 1938.
(194) JENSEN, ORLA. Centbl. Bakt. Abt. 2. 1902. (Original not seen.) Exp. Sta. Rec., 14: 289. 1902–03.
(195) JONES, J. H. J. Biol. Chem., 75: 139–146. 1927.
(196) JOSEPHSON, D. V., AND DOAN, F. J. Milk Dealer, 29: 35. 1939.
(197) JOYNER, N. T., AND MCINTYRE, J. E. Oil and Soap, 15: 184–186. 1938.
(198) KENDE, S. Milchw. Forsch., 13: 111. 1932.
(199) KERR, R. H., AND SORBER, D. G. Ind. and Eng. Chem., 15: 383–385. 1923.
(200) KERTESZ, T. Molkerei-Zeitung (Hildesheim), 46: 687. 1932. (Original not seen.)
(201) KERTESZ, T. Osterr. Milchwirtschaft Ztg., 41: 255–256. 1934. (Original not seen.) Chem. Abs., 29: 1525. 1935.
(202) KIEFERLE, F., AND SEUSS, A. World's Dairy Congress, Berlin, 2: 129–133. 1937.
(203) KILDEE, H. H. Ann. Rept. Minn. Agr. Exp. Sta., 25: 48–49. 1917.
(204) KOBERT, K. Zt. Anal. Chem., 46: 711. 1907. (Original not seen.)
(205) KOCHLING, J., AND TAUFEL, K. Fette u. Seifen, 46: 127–131. 1939. (Original not seen.) Chem. Abs., 33: 4445. 1939.
(206) KOENIG, V. L. Nat. Butter and Cheese J., 28: 26. 1937.
(206a) KOENIG, V. L. Dairy Ind., 3: 20. 1938.
(207) KON, S. K. Science, 85: 119. 1937.
(208) KON, S. K., AND WATSON, M. B. Biochem. J., 30: 2273–2290. 1936.
(209) KOOPER, W. D. Milch-Zeitung, 40: 285. 1911. (Original not seen.)
(210) KRAUSS, W. E., AND WASHBURN, R. G. Ohio Agr. Exp. Sta. Bull. 532, 6, 363. 1934.

(211) KRAUSS, W. E., AND WASHBURN, R. G. J. Biol. Chem., **114**: 247. 1936.
(212) KRENN, J. World's Dairy Congress, Milan, Sect. II, pp. 169–175. 1934.
(213) KRENN, J. World's Dairy Congress, Berlin, **3**: 477–480. 1937.
(214) LAQUE, F. L., AND SEARLE, H. E. N. Y. Bul. T.S.1, 12. 1930. (Original not seen.) Chem. Abs., **26**: 2798. 1932.
(215) LEA, C. H. Proc. Roy. Soc. London, **108B**: 175. 1931. (Original not seen.)
(216) LEA, C. H. Food Invest. Board, pp. 26–28. 1936. (Original not seen.) Chem. Abs., **32**: 2236. 1938.
(217) LEA, C. H. Food Invest. Board, p. 38. 1935. (Original not seen.)
(218) LIDOW, A. Vyestnik Shirov Veshch., **4**: 151. 1903. (Original not seen.) Exp. Sta. Rec., **15**: 606. 1903–04.
(219) LIEBSCHER, W. World's Dairy Congress, Berlin, **1**: 130–134. 1937.
(220) LOFTUS-HILLS, SCHARP, L. R., AND BELLAIR, T. S. J. Dairy Res., **2**: 124. 1934.
(221) LOWEN, L., ANDERSON, L., AND HARRISON, R. W. Ind. and Eng. Chem., **29**: 151. 1937.
(222) LOY, W. C., HILTON, J. H., WILBUR, J. W., AND HAUGE, S. M. J. DAIRY SC., **20**: 31–36. 1937.
(223) LUCAS, P. S., BALL, C. D., VINCENT, R. E., AND TROUT, G. M., Mich. Agr. Exp. Sta. Quar. Bull., **14**: 38–41. 1931.
(224) MAACK, A. C., AND TRACY, P. H. Ice Cream Rev., JAN., p. 82. 1938.
(225) MACK, M. J., AND FELLERS, C. R. Mass. Agr. Exp. Sta. Bull. 287. 1932.
(226) MACLEAN, I. S., AND PEARCE, M. S. B. Biochem. J., **25**: 1252. 1931.
(227) MAJER, G. Hild. Molk. Ztg., **45**: 1882–1884. 1931. (Original not seen.)
(228) MAJER, G. Molkerei Ztg. (Hildescheim), **46**: 1943. 1932. (Original not seen.)
(229) MARCUS, J. K. J. Biol. Chem., **90**: 507. 1931.
(230) MARCUS, L., AND HUYGE, C. L'Industrie Laitere, **30**: 187. 1905. (Original not seen.)
(231) MARQUARDT, J. C. Milk Dealer, **22**: 39. 1932.
(232) MARTIN, W. H. Inter. Assoc. Milk Dealers, Lab. Sect., p. 169. 1937.
(233) MARTIN, W. H. Milk Dealer, **27**: 88. 1937.
(234) MATILL, H. A. J. Amer. Med. Assoc., **89**: 1505. 1927.
(235) MATILL, H. A. J. Biol. Chem., **90**: 141. 1931.
(236) MATILL, H. A., AND CRAWFORD, B. Ind. and Eng. Chem., **22**: 341. 1930.
(237) MATTICK, A. T. R. J. Agr. Sci., **17**: 388. 1927.
(238) MAVEETY, D. J. U. S. Patent 2, 124, 706. 1938. (Original not seen.)
(239) MCCOLLUM, E. V., SIMMONDS, N., AND BECKER, J. E. Proc. Soc. Exp. Biol. and Med., **24**: 952. 1927.
(240) MCKAY, R. J., FRASER, O. B. J., AND SEARLE, H. E. Amer. Inst. Mining and Metall. Eng., N. Y., Tech. Pub. No. 192. 1929. (Original not seen.)
(241) MCKAY, G. L., AND LARSEN, C. Principles and Practice of Buttermaking, p. 194. 1906.
(242) MICHELS, J. Creamery Butter Making, p. 70. 1904.
(243) MISCALL, J. C., CAVENAUGH, G. W., AND CARDEMUS, P. P. J. DAIRY SC., **12**: 379–384. 1929.
(244) MIWA, S. Nagoya Igakki Zasshi, **46**: 765. 1937. (Original not seen.) Chem. Abs., **33**: 4333. 1939.
(245) MOHR, W. Molkerei-Ztg. (Hildesheim), **50**: 1454. 1936. (Original not seen.) Chem. Abs., **31**: 1108. 1937.
(246) MOHR, W., AND WELLM, J. Molkerei-Ztg. (Hildesheim), **57**: 1057. 1936. (Original not seen.) Chem. Abs., **30**: 6836. 1936.
(247) MONALGALM, B. R., AND SCHMIDT, F. O. J. Biol. Chem., **96**: 387. 1932.
(248) MORGAN, W. R. Ind. and Eng. Chem., **27**: 1287. 1935.

(249) Morris, A. J., and Sommer, H. H. Wis. Agr. Exp. Sta. Bull. 421, p. 132. 1932. (Ann. Rept.)
(250) Morris, A. J., and Sommer, H. H. Ice Cream Trade J., 28: 29. 1932.
(251) Mortensen, M. J. Dairy Sc., 7: 460. 1924.
(252) Moureu, C., and Dufraisse, C. Comp. Rend., 178: 824. 1924. (Original not seen.) Chem. Abs., 18: 2635. 1924.
(253) Moureu, C., Dufraisse, C., and Lotte, P. Ind. and Eng. Chem., 22: 549. 1930.
(254) Mudge, C. S., and Tucker, L. O. Ice Cream Field, 19: 340. 1931.
(255) Mueller, W. S., and Mack, M. J. Ice Cream Trade J., 33: 24. 1937.
(256) Murrill, P. I. U. S. Patent 1, 852, 787. 1932. (Original not seen.) Chem. Abs., 26: 3130. 1932.
(257) Nagel, Werner, and Von Have, R. Wiss. Veroffentl. Siemens-Werken, 17: 48. 1938. (Original not seen.) Chem. Abs., 32: 5239. 1938.
(258) Nestrelayev, A. Milchw. Zentbl. 6: 1. 1910. (Original not seen.) Chem. Abs., 4: 836. 1910.
(259) Newton, R. C. Oils and Soap, 9: 247. 1932.
(260) Okuyama, S. Milk Dealer, 14: 45. 1927.
(261) Olcott, H. S. J. Amer. Chem. Soc., 56: 2492–2493. 1934.
(262) Olcott, H. S., and Emerson, O. H. J. Amer. Chem. Soc., 59: 1008–1009. 1937.
(263) Olcott, H. S., and Matill, H. A. J. Amer. Chem. Soc., 58: 2204–2208. 1936.
(264) Olcott, H. S., and Matill, H. A. Oil and Soap, 13: 98–100. 1936.
(265) Olcovich, H. S., and Matill, H. A. J. Biol. Chem., 91: 105. 1936.
(266) Osborne, T. B., and Leavenworth, C. S. J. Biol. Chem., 28: 109. 1916.
(267) Overman, O. R. Nat. Butter and Cheese J., 27: 6. 1936.
(268) Overman, O. F., Garrett, O. F., and Ruehe, H. A. Ill. Agr. Exp. Sta. Bull. 446. 1938.
(269) Palit, C. C. J. Phys. Chem., 36: 2504. 1932.
(270) Palmer, L. S., and Combs, W. B. J. Dairy Sc., 2: 444–452. 1919.
(271) Palmer, L. S., and Dahle, C. D. J. Dairy Sc., 5: 240. 1922.
(272) Palmer, L. S., and Miller, M. M. J. Dairy Sc., 9: 272. 1926.
(273) Parsons, C. H. Nat. Butter and Cheese J., 29: 6–7. 1938.
(274) Patrick, G. E. Iowa Agr. Exp. Sta. Bull. 8, pp. 317–320. 1890.
(275) Patrick, G. E., Leighton, F. A., and Bisbee, D. B. Iowa Agr. Exp. Sta. Bull. 18, pp. 478–487. 1892.
(276) Pien, J., and Herschdoerfer, S. Le Lait, 15: 1–15. 1935. (Original not seen.) Chem. Abs., 29: 4843. 1935.
(277) Powick, W. C. J. Agr. Res., 26: 323. 1923.
(278) Prewitt, E., and Parfitt, E. H. J. Dairy Sc., 18: 468. 1935.
(279) Proks, J., and Groh, J. Le Lait, 15: 370–381. 1935. (Original not seen.) Chem. Abs., 29: 4466. 1935.
(280) Prucha, M. J., Brannon, J. M., and Ruehe, H. A. J. Dairy Sc., 8: 318. 1925.
(281) Quam, G. M. Milk Dealer, 16: 61. 1927.
(282) Quam, G. M. Ind. and Eng. Chem., 21: 703–704. 1929.
(283) Quam, G. M., Solomon, E. I., and Hellwig, A. Ind. and Eng. Chem., 20: 930–931. 1928.
(284) Rann, O., Brown, C. W., and Smith, L. M. Mich. Agr. Exp. Sta. Tech. Bull. 2. 1909.
(285) Rasmussen, R., Guerrant, N. B., Shaw, A. O., Welch, R. C., and Bechdel, S. I. J. Nutrit., 11: 425. 1936.
(286) Reed, G. B. Bot. Gaz., 57: 528–530. 1914.
(287) Reinmann, R. Centbl. Bakt. Abt., 2: 6. 1900. (Original not seen.) Exp. Sta. Rec., 12: 680. 1900–01.

(288) RICE, F. E. J. DAIRY SC., 9: 459. 1926.
(289) RICE, F. E., AND MISCALL, J. J. DAIRY SC., 6: 261. 1923.
(290) RIDDELL, W. H., WHITNAH, C. H., HUGHES, J. S., AND LIENHARDT, H. F. J. Nutrit., 11: 47–54. 1936.
(291) RITTER, W. Lebensmitteluntersuchung and Hygiene, 26: 145. 1935. (Original not seen.) J. DAIRY SC., 20: 147 (Abs.). 1937.
(292) RITTER, W. Schweiz. Milchztg., 61: 525, 531, 539. 1935. (Original not seen.) Chem. Abs., 30: 2274. 1936.
(292a) RITTER, W. Schweiz. Milchztg., 62: 25. 1935. (Original not seen.) Chem. Abs., 30: 2274. 1936.
(293) RITTER, W. Schweiz. Milchztg., 62: 59–60. 1936. J. DAIRY SC., 21: 42 (Abs.). 1938.
(294) RITTER, W. Schweiz. Milchztg., 62: 529. 1936. J. DAIRY SC., 21: 26 (Abs.). 1938.
(295) RITTER, W. World's Dairy Cong., Berlin, 2: 162. 1937.
(296) RITTER, W., AND CHRISTEN, M. Schweiz. Milchztg., 60: 373–374. 1934. (Original not seen.) Chem. Abs., 29: 1524. 1935.
(297) RITTER, W., AND CHRISTEN, M. Schweiz. Milchztg., 61: 23–24. 1935. (Original not seen.) J. DAIRY SC., 19: 218 (Abs.). 1936.
(298) RITTER, W., AND CHRISTEN, M. Schweiz. Milchztg., 61: 23–24. 1935. (Original not seen.) Chem. Abs., 29: 2611. 1935.
(299) RITTER, W., AND CHRISTEN, M. Schweiz. Milchztg., 61: 61–62, 69–70. 1936. J. DAIRY SC., 19: 218 (Abs.). 1936.
(300) RITTER, W. Aluminum, 21: 308–314. 1939. (Original not seen.) Chem. Abs., 33: 5077. 1939.
(301) RITTER, W., AND NUSSBAUMER, T. Schweiz. Milchztg., 64: 59–61. 1938. (Original not seen.) Chem. Abs., 32: 7148. 1938.
(302) RITTER, W., AND NUSSBAUMER, T. Schweiz. Milchztg., 64: 215–216. 1938. (Original not seen.) Chem. Abs., 32: 7148. 1938.
(303) RITTER, W., AND NUSSBAUMER, T. Schweiz. Milchztg., 64: 465. 1938. (Original not seen.) J. DAIRY SC., 22: 98 (Abs.). 1939.
(304) RITTER, W., AND NUSSBAUMER, T. Schweiz. Milchztg., 64: 525. 1938. (Original not seen.) J. DAIRY SC., 22: 99. 1939.
(305) RITSERT, T. Inaugural Dissertation. Bern. 1890. (Original not seen.)
(306) ROGERS, L. A. U. S. D. A., Bur. Animal Ind. Bull. 57. 1904.
(307) ROGERS, L. A., BERG, W. N., POTTEIGER, C. R., AND DAVIS, B. J. U. S. D. A., Bur. Animal Ind. Bull. 162. 1913.
(308) ROGERS, L. A., AND GRAY, C. E. U. S. D. A., Bur. Animal Ind. Bull. 114. 1909.
(309) ROGERS, L. A., THOMPSON, S. C., AND KIETHLEY, J. R. U. S. D. A., Bur. Animal Ind. Bull. 148. 1912.
(310) ROLAND, C. T., SORENSEN, C. M., AND WHITAKER, R. J. DAIRY SC., 20: 213. 1937.
(311) ROLAND, C. T., AND TREBLER, H. A. J. DAIRY SC., 20: 345–350. 1937.
(312) ROLLER, P. E. J. Phys. Chem., 35: 3286. 1931.
(313) ROSS, H. E. Milk Plant Mo., 26: 36. 1937.
(314) ROSS, O. E. Ice Cream Trade J., 29: 23–25. 1933.
(315) ROUNDY, Z. D., AND JACKSON, H. C. Wis. Agr. Exp. Sta. Bull. 428, pp. 35–36. 1934. (Ann. Rept.).
(316) RUEMELE, T. Seifensieder Ztg., 61: 125. 1934. (Original not seen.)
(317) SABALITSCHKA, T., AND BOHM, E. Brit., 498: 110. 1939. (Original not seen.) Chem. Abs., 33: 4450. 1939.
(318) SALKOWSKI, E. Ztschr. Untersuch. Nahr. u. Genussmtl., 34: 305. 1919. (Original not seen.) Chem. Abs., 14: 784. 1920.

(319) SALWAY, A. H. J. Chem. Soc., 109: 138. 1916.
(320) SALZBERG, P. L. U. S. Patent 2, 124, 749. 1933. (Original not seen.)
(321) SAMPEY, J. J. Ice Cream Rev., 22: 78. 1939.
(322) SAYER, W. S., RAHN, O., AND FARRAND, B. Mich. Agr. Exp. Sta. Tech Bull. 1. 1908.
(323) SCALA, A. Gazz. Chim. Ital., 38: 307–327. 1908. (Original not seen.) Chem. Abs., 2: 2024. 1908.
(324) SCHOENBERG, F. Z. Fleisch. u. Milchhyg., 48: 321. 1938. (Original not seen.) Chem. Abs., 32: 7150. 1938.
(325) SCHRICKER, A. C. Ice Cream Field, 26: 18. 1935.
(326) SCISM, S. F. Ice Cream Trade J., 30: 31. 1934.
(327) SHARP, P. F. Science, 84: 461. 1936.
(328) SHARP, P. F., TROUT, G. M., AND GUTHRIE, E. S. Milk Plant Mo., 26: 36. 1937.
(329) SIEGFELD, M. Milchw. Zentbl., 4: 530–532. 1908. (Original not seen.) Chem. Abs., 3: 844. 1909.
(330) SIMMONDS, N., BECKER, J. E., AND MCCOLLUM, E. V. Proc. Soc. Exp. Biol. and Med., 24: 952. 1927.
(331) SINGLETON, W. M. New Zealand Dept. Agr. Ann. Rept., 1936–37, pp. 35–40. 1937. (Original not seen.) Chem. Abs., 32: 4237. 1937.
(332) SMITH, O. M., AND WOOD, R. E. Ind. and Eng. Chem., 18: 691. 1926.
(333) SMYTHE, C. V. J. Biol. Chem., 90: 251. 1931.
(334) SMYTHE, C. V., AND SCHMIDT, C. L. A. J. Biol. Chem., 88: 241. 1930.
(335) SOMMER, H. H. Proc. World's Dairy Congress, 2: 974. 1923.
(336) SOMMER, H. H. Ice Cream Rev., 20: 62. 1937.
(337) SOMMER, H. H., AND GEBHARDT, H. Wis. Exp. Sta. Bull. 410, p. 29. 1930. (Ann. Rept.)
(338) STEBNITZ, V. C., AND SOMMER, H. H. J. DAIRY SC., 20: 181. 1937.
(339) STEBNITZ, V. C., AND SOMMER, H. H. J. DAIRY SC., 20: 265. 1937.
(340) STEBNITZ, V. C., AND SOMMER, H. H. Oil and Soap, 14: 228. 1937.
(341) STIEPEL, C. Chem. Umschau Fette, Ole. Wachse Harze, 39: 83. 1932. (Original not seen.) Chem. Abs., 26: 3394. 1932.
(342) STOCKER, W. Proc. World's Dairy Congress, Berlin, 2: 58. 1937.
(343) STOKOE, W. N. J. Soc. Chem. Ind., 40: 75. 1921.
(344) STRYNADKA, N. J., AND THORNTON, H. R. J. DAIRY SC., 21: 561. 1938.
(345) STUTZ, G. F. A., NELSON, H. A., AND SCHMUTZ, F. C. Ind. and Eng. Chem., 17: 1138. 1925.
(346) SUPPLEE, G. C., AND BELLIS, B. J. DAIRY SC., 5: 455. 1922.
(347) SWANSON, A. M., AND SOMMER, H. H. J. DAIRY SC., 23: 201. 1940.
(348) TAKAHASHI, EIJI, AND MASUDA, Y. J. Agr. Chem. Soc. Japan, 14: 19. 1938. (Original not seen.) Chem. Abs., 32: 6087. 1938.
(349) TAUFEL, K. Fette u. Seifen, 45: 179. 1938. (Original not seen.) Chem. Abs., 31: 6351. 1938.
(350) TAUFEL, K., AND THALER, H. Chem. Ztg., 56: 265. 1932. (Original not seen.) Chem. Abs., 26: 3394. 1932.
(351) TAYLOR, M. W. Iowa State Coll. J. Sci., 5: 355. 1931.
(352) THATCHER, R. W., AND DAHLBERG, A. C. J. Agr. Res., 11: 437. 1917.
(353) THOMSEN, L. C. Nat. Butter and Cheese J., 26: 30. 1935.
(354) THORNTON, H. R., AND HASTINGS, E. G. J. Bact., 18: 293. 1929.
(354a) THORNTON, H. R., AND HASTINGS, E. G. J. DAIRY SC., 13: 221. 1930.
(355) THURSTON, L. M. Proc. Inter. Assoc. Milk Dealers, Lab. Sect., p. 121. 1935.
(356) THURSTON, L. M. Milk Dealer, 26: 112. 1937.
(357) THURSTON, L. M. Proc. Inter. Assoc. Milk Dealers, Lab. Sec., p. 143. 1937.

(358) THURSTON, L. M., AND BARNHART, J. L. J. DAIRY SC., 18: 131. 1935.
(359) THURSTON, L. M., BROWN, W. C., AND DUSTMAN, R. B. J. DAIRY SC., 18: 301. 1935.
(360) THURSTON, L. M., BROWN, W. C., AND DUSTMAN, R. B. J. DAIRY SC., 19: 671. 1936.
(361) THURSTON, L. M., AND OLSON, H. C. W. Va. Agr. Exp. Sta. Bull. 255. 1933.
(362) TRACY, P. H. Ice Cream Field, 30: 58. 1930.
(363) TRACY, P. H. Milk Dealer, 21: 68–69. 1931.
(364) TRACY, P. H. Milk Dealer, 25: 114. 1936.
(365) TRACY, P. H., RAMSEY, R. J., AND RUEHE, H. A. Ice Cream Trade J., 29: 40. 1933.
(366) TRACY, P. H., RAMSEY, R. J., AND RUEHE, H. A. Ill. Agr. Exp. Sta. Bull. 389. 1933.
(367) TRACY, P. H., RAMSEY, R. J., AND RUEHE, H. A. Ill. Agr. Exp. Sta. Bull. 407. 1934.
(368) TRACY, P. H., AND RUEHE, H. A. J. DAIRY SC., 14: 250. 1931.
(369) TREBLER, H. A., WESLEY, W. F., AND LA QUE, F. L. Ind. and Eng. Chem., 24: 339. 1932.
(370) TRIEBOLD, H. O. Cereal Chem., 8: 518. 1931.
(371) TRIEBOLD, H. O., AND BAILEY, C. H. Cereal Chem., 9: 91. 1932.
(372) TROUT, G. M. Proc. Inter. Assoc. Milk Dealers, Lab. Sect., p. 131. 1937.
(373) TROUT, G. M., AND GOULD, I. A. Mich. Agr. Exp. Sta. Quart. Bull., 21: 1. 1938.
(374) TROUT, G. M., AND GJESSING, E. C. J. DAIRY SC., 22: 271. 1939.
(375) TROUT, G. M., AND SHARP, P. F. Cornell U. N. Y. Agr. Exp. Sta. Mem. 204. 1937.
(376) TSCHIRCH, A. Chem. Umschau., 32: 29. 1925. (Original not seen.) Chem. Abs., 19: 1557. 1925.
(377) TSCHIRCH, A., AND BARBEN, A. Schweiz. Apoth. Ztg., 62: 281. 1924. (Original not seen.) Chem. Abs., 18: 2970. 1924.
(378) TUCKER, H. H., GARRETT, O. F., AND BENDER, C. B. J. DAIRY SC., 21: 108. 1938.
(379) TURGEON, J., STEBNITZ, V. C., AND SOMMER, H. H. J. DAIRY SC., 20: 475. 1937.
(380) TURGEON, J. P., STEBNITZ, V. C., AND SOMMER, H. H. Wis. Agr. Exp. Sta. Bull. 439. 1937.
(381) VANDEVELDE, A. J. J. Le Lait, 3: 437. 1923. (Original not seen.) Chem. Abs., 17: 3211. 1923.
(382) VINCENT, V. Ann. Sci. Agron. Franc. et Etrang., Ser. 3, 2: 269. 1909. (Original not seen.) Chem. Abs., 4: 392. 1910.
(383) VON KLECKI, V. Milch. Ztg., 23: 186. 1894. (Original not seen.)
(384) VOSS-SCHRADER, A. Landtmannen, 14: 663. 1903 (Original not seen.) Exp. Sta. Rec., 15: 1117. 1903–04.
(385) WARBURG, O. Biochem. Z., 152: 479. 1924.
(386) WASHBURN, R. M., AND DAHLBERG, A. C. J. DAIRY SC., 1: 114. 1917.
(387) WEBB, R. E., AND HILEMAN, J. L. J. DAIRY SC., 19: 476. 1936.
(388) WEBB, R. E., AND HILEMAN, J. L. J. DAIRY SC., 20: 47. 1937.
(389) WECKEL, K. G. Ice Cream Rev., 21: 35. 1938.
(390) WECKEL, K. G., JACKSON, H. C., HAMAN, R., AND STEENBOCK, H. Wis. Agr. Exp. Sta. Bull. 435. (Ann. Rept. 1934–5.)
(391) WEICH, A., AND BAUER, R. Forschr. Landw., 7: 7–9. 1932. (Original not seen.) Chem. Abs., 26: 2685. 1932.
(392) WEIGMANN, H. Milch. Ztg., 20: 1019. 1891. (Original not seen.) Exp. Sta. Rec., 5: 1053. 1893–4.
(393) WEILAND, H., AND FRANKE, W. Ann. Chem., 457: 1. 1927.
(394) WEILAND, H., AND FRANKE, W. Ann. Chem., 464: 101. 1928.

(395) Weiland, H., and Franke, W. Ann. Chem., 475: 1. 1929.
(396) Wesley, W. A., Trebler, H. A., and La Que, F. L. Trans. Electrochem. Soc., 61. 1932. (Original not seen.) Chem. Abs., 26: 2685. (1932).
(397) Wheeler, D. H. Oil and Soap, 9: 89. 1932.
(398) White, W., and Campbell, G. R. J. Dairy Sc., 8: 497. 1925.
(399) White, W., Trimble, C. S., and Wilson, H. L. U. S. D. A. Tech. Bull. 159. 1929.
(400) Whitehead, H. R. Biochem. J., 24: 579. 1924.
(401) Whitehead, H. R. Biochem. J., 25: 1647. 1931.
(402) Whitfield, B. H., Davis, H. P., and Downs, P. A. Milk Dealer, 24: 34. 1934.
(403) Whitnah, C. H., Martin, W. H., and Beck, G. H. J. Dairy Sc., 20: 431. 1937.
(404) Whitnah, C. H., Peterson, W. J., Atkeson, F. W., and Cave, H. W. Abstracts, 94th Meeting, Amer. Chem. Soc., Rochester, N. Y. 1937.
(405) Whitnah, C. H., Peterson, W. J., Atkeson, F. W., and Cave, H. W. J. Agr. Res., 58: 343. 1939.
(406) Whitnah, C. H., Riddell, W. H., and Caulfield, W. J. J. Dairy Sc., 19: 373. 1936.
(407) Wiley, W. J. J. Council Sci. Ind. Res., 10: 327. 1937.
(408) Winckel, M. Chem. Ztg., 36: 415. 1913. (Original not seen.) Chem. Abs., 7: 1785. 1913.
(409) Wright, K. E., and Overman, O. R. Le Lait, 11: 564. 1931. (Original not seen.)
(410) Yamaguchi, B. J. Chem. Soc. Japan, 53: 54. 1932. (Original not seen.) Chem. Abs., 27: 201. 1933.
(411) Zilva, S. S. Biochem. J., 13: 164. 1919.
(412) Zondick, S. G., and Bondman, M. Klin. Wochnschr., 10: 1528. 1931. (Original not seen.) Chem. Abs., 26: 184. 1932.

REPORT OF THE STUDENTS' NATIONAL CONTEST IN JUDGING DAIRY CATTLE

SAN FRANCISCO, CALIFORNIA, OCTOBER 21, 1939

Seventeen teams competed in the Dairy Cattle Judging Contest held on Treasure Island in conjunction with the National Dairy Show and the Golden Gate International Exposition. The Iowa State College team won first honors on all breeds and Robert Lage of Iowa State was high individual of the contest.

Breed honors were divided, with the Texas A. & M. College team ranking first in Ayrshires and Brown Swiss. A. A. Price, of the Texas A. & M. team, was high individual in judging Ayrshires, while individual honors on Brown Swiss went to D. C. Marsh of the same team.

The Guernsey trophy was won by the team from the University of Missouri with individual high score being made by A. A. Price of Texas A. & M. College.

In judging Holsteins, South Dakota State College won first in team standings, while Paul Astleford of Oregon State College was high ranking individual.

First rank in team standings in Jersey judging was won by the University of Wisconsin. T. H. Blosser of Purdue University was high ranking individual and won the $400 Research Scholarship awarded by the American Jersey Cattle Club.

The ten high ranking individuals and the team rank for the various divisions of the contest are indicated in the following lists:

ALL BREEDS

Individuals

1. Robert Lage, Iowa State College
2. A. A. Price, Texas A & M College
3. E. Halbach, University of Wisconsin
4. Quinten Syse, University of Wisconsin
5. Paul Astleford, Oregon State College
6. Russel Pfeiffer, University of Nebraska
7. T. H. Blosser, Purdue University
8. Alva Clark, University of Missouri
9. Gilbert Walker, Oklahoma A & M College
10. Raymond French, University of Illinois

Teams

1. Iowa State College
2. Oklahoma A & M College
3. Texas A & M College
4. University of Wisconsin
5. University of Nebraska
6. University of Missouri
7. Purdue University
8. Oregon State College
9. Texas Technological College
10. University of Illinois
11. University of Tennessee
12. University of Minnesota
13. South Dakota College
14. New Mexico College of Agriculture
15. Kansas State College
16. Pennsylvania State College
17. University of Georgia

AYRSHIRES

Individuals

1. A. A. Price, Texas A & M College
2. Jack Hancock, Texas Technological College
3. Chas. Bennett, University of Illinois
4. Tom Miles, University of Tennessee
5. Dallas Rierson, New Mexico College of Agriculture
6. Donald Jordan, University of Minnesota
7. Alva Clark, University of Missouri
8. Eugene Halbach, University of Wisconsin
9. Gilbert Walker, Oklahoma A & M College
10. W. C. Foster, Texas A & M College

Teams

1. Texas A & M College
2. University of Minnesota
3. University of Nebraska
4. Purdue University
5. University of Tennessee
6. Oklahoma A & M College
7. University of Wisconsin
8. New Mexico College of Agriculture
9. Texas Technological College
10. University of Illinois
11. Oregon State College
12. University of Missouri
13. Pennsylvania State College
14. University of Georgia
15. Iowa State College
16. South Dakota State College
17. Kansas State College

BROWN SWISS

Individuals

1. D. C. Marsh, Texas A & M College
2. Fred Giesler, University of Minnesota
3. Quinten Syse, University of Wisconsin
4. A. A. Price, Texas A & M College
5. Claire Wemer, Iowa State College
6. Willis Jones, University of Georgia
7. Elmont Honea, Texas Technological College
8. Jack Hancock, Texas Technological College
9. Alva Clark, University of Missouri
10. Paul Astleford, Oregon State College

Teams

1. Texas A & M College
2. Texas Technological College
3. Purdue University
4. University of Missouri
5. New Mexico College of Agriculture
6. Iowa State College
7. University of Tennessee
8. University of Wisconsin
9. Oklahoma A & M College
10. University of Minnesota
11. University of Illinois
12. Oregon State College
13. University of Nebraska
14. University of Georgia
15. Kansas State College
16. Pennsylvania State College
17. South Dakota State College

GUERNSEYS

Individuals

1. A. A. Price, Texas A & M College
2. T. H. Blosser, Purdue University
3. Richard Schuckenbrock, University of Missouri
4. Gilbert Walker, Oklahoma A & M College
5. George Smith, University of Illinois
6. Wm. H. Winner, Kansas State College
7. Tom Miles, University of Tennessee
8. Otto Pfeiffer, Jr., University of Nebraska
9. Russell Pfeiffer, University of Nebraska
10. B. I. Iffit, Pennsylvania State College

Teams

1. Oklahoma A & M College
2. Texas A & M College
3. University of Missouri
4. Texas Technological College
5. Kansas State College
6. University of Nebraska
7. University of Tennessee
8. South Dakota State College
9. New Mexico College of Agriculture
10. Iowa State College
11. University of Georgia
12. University of Wisconsin
13. Purdue University
14. University of Illinois
15. University of Minnesota
16. Pennsylvania State College
17. Oregon State College

HOLSTEINS

Individuals

1. Paul Astleford, Oregon State College
2. Eugene Halbach, University of Wisconsin
3. Raymond French, University of Illinois
4. Clifford Manry, Oklahoma A & M College
5. Elmer Dent, Oregon State College
6. Ray Johnson, University of Minnesota
7. L. G. Duncan, New Mexico College of Agriculture
8. Jacob Stimson, Iowa State College
9. George Smith, University of Illinois
10. Melvin Jensen, South Dakota State College

Teams

1. South Dakota State College
2. Oregon State College
3. University of Illinois
4. Iowa State College
5. New Mexico College of Agriculture
6. Oklahoma A & M College
7. Kansas State College
8. University of Minnesota
9. University of Wisconsin
10. Pennsylvania State College
11. Texas Technological College
12. University of Nebraska
13. University of Tennessee
14. Texas A & M College
15. University of Missouri
16. Purdue University
17. University of Georgia

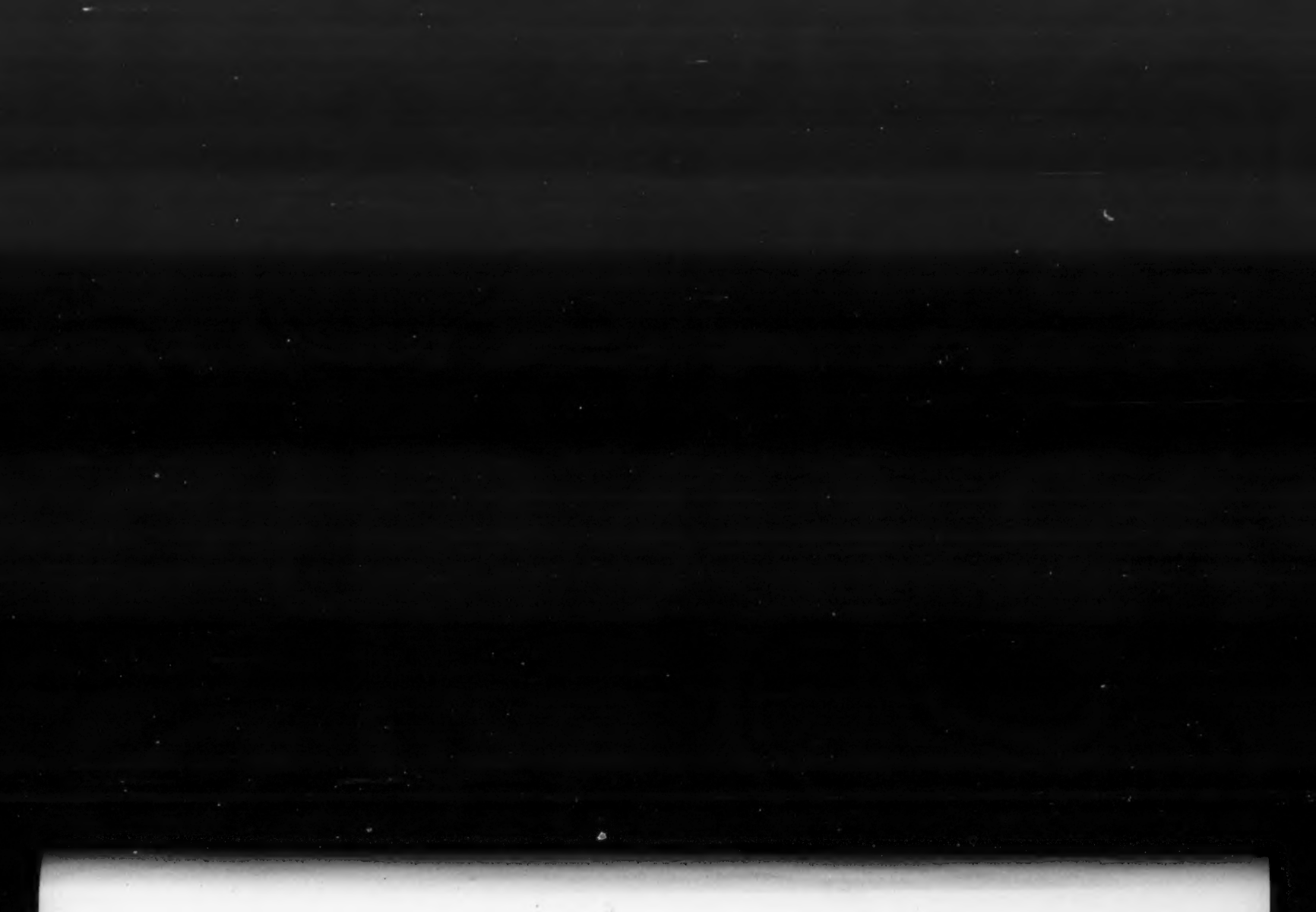
JERSEYS

Individuals

1. T. H. Blosser, Purdue University
2. Robert Lage, Iowa State College
3. John Liggett, Oklahoma A & M College
4. Eugene Halbach, University of Wisconsin
5. Otto Pfeiffer, Jr., University of Nebraska
6. Quinten Syse, University of Wisconsin
7. Phillip E. Kizer, University of Missouri
8. Claire Wemer, Iowa State College
9. Clayton Fox, Oregon State College
10. Willis Jones, University of Georgia

Teams

1. University of Wisconsin
2. Iowa State College
3. Oklahoma A & M College
4. University of Missouri
5. University of Nebraska
6. Purdue University
7. Oregon State College
8. University of Tennessee
9. University of Minnesota
10. University of Illinois
11. Kansas State College
12. Texas A & M College
13. South Dakota State College
14. Texas Technological College
15. Pennsylvania State College
16. University of Georgia
17. New Mexico College of Agriculture



VOLUME XXIII JULY, 1940 NUMBER 7

JOURNAL OF DAIRY SCIENCE

Published by the
AMERICAN DAIRY SCIENCE ASSOCIATION
R. B. STOLTZ, Sec.-Treas.
Ohio State University, Columbus, Ohio

ABSTRACTS OF LITERATURE

T. S. SUTTON, Editor
Columbus, Ohio

MILK AND MILK PRODUCTS

Published in cooperation with
INTERNATIONAL ASSOCIATION OF ICE CREAM MANUFACTURERS
R. C. HIBBEN, 1105 Barr Bldg., Washington, D. C., Exec. Sec.

INTERNATIONAL ASSOCIATION OF MILK DEALERS
R. E. LITTLE, 309 W. Jackson Blvd., Chicago, Illinois, Exec. Sec.

Editorial Committee

H. H. SOMMER, Madison, Wisconsin, A. D. S. A.
G. D. TURNBOW, Oakland, California, I. A. I. C. M.
HAROLD PRATT, Philadelphia, Pennsylvania, I. A. I. C. M.
W. D. DOTTERRER, Chicago, Illinois, I. A. M. D.
A. J. POWERS, Brooklyn, New York, I. A. M. D.

CONTENTS

Bacteriology
Breeding
Butter
Cheese
Chemistry
Concentrated and dry milk; by-products
Diseases
Feeds and feeding
Food value of dairy products
Herd management
Ice cream
Milk
Miscellaneous
Physiology

THE SCIENCE PRESS PRINTING COMPANY LANCASTER, PA.

PUBLICATIONS AND ABSTRACTORS

EDITORS

Dahle, C. D., Dahlberg, A. C., Elliker, P. R., Petersen, W. E., Tracy, P. H. and Weckel, K. G.

ABSTRACTORS

Anderson, E. O.
Archibald, J. G.

Babcock, C. J.
Brueckner, H. J.
Burgwald, L. H.
Bushnell, L. D.

Cole, W. C.
Coulter, S. T.

Doan, F. J.
Dorsey, L. M.
Downs, P. A.

Erb, J. H.
Espe, D. L.

Frazier, W. C.

Garrett, O. F.
Goss, E. F.

Hansen, Arne
Herrington, B. L.
Huffman, C. F.

Irvine, O. R.

Josephson, D. V.

Knight, D.

Lucas, P. S.
Lush, J. L.

Mack, M. J.
Macy, H.
Marquardt, J. C.
Martin, W. H.
Mueller, W. S.

Parfitt, E. H.
Price, W. V.

Reece, Ralph P.
Ritter, W.

Stark, C. N.

Thomsen, L. C.
Trout, G. M.
Tuckey, S. L.

Webb, B. H.
Weckel, K. G.
White, G. C.

Yale, M. W.

JOURNALS

American Butter Review
American Milk Review
American Journal of Diseases of Children
American Journal of Physiology
American Journal of Public Health
Archives of Pediatrics

Biochemical Journal
Biochemische Zeitschrift

Canadian Dairy and Ice Cream Journal
Canadian Public Health Journal
Certified Milk
Cornell Veterinarian

Dairy Industries
Dairy World
Deutsche Molkerei Zeitung

Endocrinology

Food Industries
Food Manufacture
Food Research

Ice and Refrigeration
Ice Cream Field
Ice Cream Industry
Ice Cream Review
Ice Cream Trade Journal
Industrial and Engineering Chemistry

Journal of Agricultural Research
Journal of Agricultural Science
Journal of American Veterinary Medicine Association
Journal of Bacteriology
Journal of Biological Chemistry
Jorunal of Dairy Research
Journal of Dairy Science
Journal of Endocrinology
Journal of Experimental Medicine
Journal of General Physiology
Journal of Heredity
Journal of Genetics
Journal of Infectious Diseases
Journal of Milk Technology
Journal of Nutrition
Journal of Pathology and Bacteriology
Journal of Physical Chemistry
Journal of Physiology

Kaeseindusfrie
Kolloid-Zeitschrift

Lancet
Le Lait

Milchwirtschaftliche Forschungen
Milchwirtschaftliche Zeitung
Milk Dealer
Milk Industry
Milk Plant Monthly
Molkerei Zeitung
National Butter and Cheese Journal

Pacific Dairy Review
Proceedings of Society of Animal Production
Proceedings of Society of Experimental Biology and Medicine

Refrigerating Engineering

Scientific Agriculture

Tierernährung
Tierzüchter

Zeitschrift für Infektionskrankheiten Parasitäre Krankheiten und Hygiene der Haustiere
Zeitschrift für Physikalische Chemie, Abt. A and B
Zeitschrift für Untersuchtung der Lebensmittel
Zeitschrift für Züchtung. Reihe B. Tierzuchtung und Zuchtungbiologie
Zentralblatt für Bacteriologie
Züchtungskunde

SPECIAL PUBLICATIONS

Federal Dairying and Bacteriological Establishment, Liebefeld, Berne, Switzerland

International Association of Ice Cream Manufacturers
International Association of Milk Dealers

National Institute for Research in Dairying, Reading, England
New York Association of Dairy and Milk Inspectors

Prussian Dairy Research Institute, Kiel, Germany

State Agricultural Colleges and Experiment Stations

The Royal Technical College, Copehagen, Denmark

United States Department of Agriculture

ABSTRACTS OF LITERATURE

BACTERIOLOGY

217. Chromorésistence et Enrobage Phosphocalcique des Microbes Chauffés dans le Lait (2). (Resistence of Staining and Phosphocalcic Enrobage of Organisms Heated in Milk.) M. G. Guittonneau and M. Bejamber. Le Lait, *19:* 225. March, 1939.

In a former study, it was shown that certain micro-organisms displayed a definite resistance to staining after being subjected to heat in a milk medium. This "white image phenomenon" could be produced by heating the organisms in raw skim milk for one hour at 100° C. or by a similar temperature treatment in a medium of calcium caseinate and calcium phosphate at pH 6.7.

A strain of *Str. thermophilus* was used in the present study. After being heated in milk for one hour, the bacteria displayed the stain resisting property. This could not be altered by washing the organisms in decinormal alkali but it was removed by dilute acids and CO_2. Micro-analytical methods applied to a suspension of the enrobed cells indicated that the covering was probably $Ca_3(PO_4)_2$ absorbed on the outer cell membrane. O.R.I.

218. Les Formes S et R Des Colonies Chez Les Colibacilles. (S and R Forms of Baccillus Coli Colonies). Irene Lipska, Municipal Institute of Hygiene, Warsaw. Le Lait, *19:* 1016–1027. 1939.

Interest had centered for some time on the types of colonies produced by colon organisms. The causes of variations and the difference in virulence of the two forms is not yet fully understood. The author reports that most natural sources—milk, butter, feces, pathological urines—produce the S form in the greatest numbers but that the majority of colonies from cheese were of the rough colony type.

Using Endo's agar at 37° C. and carbohydrate broths, a study was made of several factors affecting colony types. Drying of the agar surface of plates caused the R forms to revert to the S form. Low incubation temperatures favor this change. The addition of gelatine and of bile to Endo's agar favored the growth of the R and the intermediate forms. The R form when so obtained in the laboratory is not stable however.

There is little or no difference in the reaction of the two forms to the action of bacteriophages. When new cultures were used for determining this activity, the phage dissolved colonies of its own form more rapidly than those of the other type of colony. O.R.I.

219. Recherches sur les Bacteries Propionique (Studies on the Propionic Bacteria). W. Dorner. Le Lait, *19:* 897–918. 1939.

This paper is an important contribution to our knowledge of Swiss cheese

cultures. Examinations were made of the milk received, and of the rennet and starters used in many of the cheese plants in Switzerland. Counts were made on samples by heating them to 58° F. for five minutes and determining the surviving organisms capable of growing on a yeast extract-peptone-sodium lactate-agar medium.

Some sources of milk were found to have comparatively high counts of propionic bacteria. In most cases rennet and ripened whey were not important sources. Examinations of asceptically drawn cow's milk show comparatively high counts in many cases.

Work is reported on the effect of propionic bacteria cultures upon eye formation and density. In most cases eye formation was increased where light inoculations were employed. Heavy inoculations increased the content of propionic acid bacteria in cheese but did not favor eye formation. The final specific gravities of inoculated and control cheeses were the same at the end of three months although the desired condition was brought about earlier in the case of the inoculated cheese.

Propionic bacteria were found to consist of two types; cocci and rods. Forty-five strains of the coccus form were isolated and their cultural characteristics determined. By holding these on agar slants for 30 to 45 days at 30° C. the cocci gave rise to the rod forms. No means was found of reverting rods to cocci however.

Most strains of cocci grew best at 30° C. and had maximum growth temperatures of 42–50° C. Both propionic and acetic acids were produced, usually in the ratio of 2 : 1. Milk was coagulated and the following carbohydrates hydrolysed: glycine, levulose, dextrose, mannose, galactose, sucrose, maltose and lactose. Gelatin was not liquefied. O.R.I.

220. Microscopic Examination of Dairy Products and Their Calculations. HANS EDEL, Gehl's Guernsey Farms, Milwaukee, Wis. Milk Dealer, *29:* 5, 34–35. Feb. 1940.

The author presents a chart which eliminates any figuring when using the Breed smear method for determining the number of bacteria in dairy products. C.J.B.

BUTTER

221. Neutralizing Cream for Buttermaking. I. A. GOULD AND R. C. TOWNLEY. Can. Dairy and Ice Cream J., *19:* 2, 48. 1940.

Soda neutralizers were found to be more efficient than limes in lowering the acidity of butter and butterfat. The acidity of butterfat was found to be lower than that of the butter but the extent of the difference varies somewhat with the type and amount of neutralizer used. The degree of neutralization of each batch of cream needs careful consideration.

O.F.G.

222. The Deterioration of Butter in Storage. W. C. CAMERON. Can. Dairy and Ice Cream J., *19:* 2, 22. 1940.

Most of the flavor defects in butter are probably due to either bacterial or chemical action in the cream or butter. The extent to which these flavor defects occur in butter can be materially reduced by: (1) withholding from churnings intended as first grade all cream showing unclean or stale flavors regardless of the acid content of the cream; (2) sanitary conditions in the creamery being measured by frequent and systematic mold analyses, and necessary control measures as indicated by the results of such analyses being applied; (3) giving due consideration to the type of package used and the temperatures at which butter is held immediately after churning and until entering storage for long holding. O.F.G.

223. The Creamery Industry under War-Time Conditions. C. E. LACKNER. Can. Dairy and Ice Cream J., *18:* 12, 47. 1939.

Under war-time conditions the disposition of surpluses is not a problem of Canadian butter manufacturers but there is the problem of increased production to meet a greater demand. The problem is really one of increased milk production rather than a shift in amount from one type of product made from milk to another. The methods suggested for bringing about increased production are first, increasing the number of cows in the herd, and second, increasing the yield per cow. O.F.G.

224. Butter—A Vital Food. W. A. SPROULE. Can. Dairy and Ice Cream J., *18:* 12, 15. 1939.

This is partly a discussion of the importance of butter in a war economy. The importance of butter in the human diet especially from the standpoint of fat digestibility and vitamin A and D content is emphasized. Butter is prized above most other edible fats because of its superior flavor but it is not only flavorful in itself, but adds to that of other foods consumed with it. There is no butter substitute acceptable by people who realize the true value of butter if the finest quality is available. O.F.G.

225. A Discussion of Butter Working Methods. H. MCNEVIN. Can. Dairy and Ice Cream J., *18:* 10, 45. 1939.

This article emphasizes the importance of treatment of a new churn barrel. The inside diameter should be checked to be sure the sides are parallel and to be sure that the churn is level. Lime, washing compounds or acids should never be used but scalding hot water should be employed in cleaning the churn. O.F.G.

226. Cow Butter. B. F. McKibben. Pacific Dairy Review *44:* 3. 1940.

The southern housewife often calls home-made butter "cow butter," while creamery butter is considered second grade.

As flavor is the basic factor for determining the quality of butter, the housewife's distaste of the manufactured product may be due to the flavor of the water used in the creamery. Numerous off-flavors, such as the "cheesy" and "oily" flavors, may be caused by impure wash water.

V. L. Turgasen of Armour and Company reached the conclusions that water supplies from rather widespread areas are capable of bringing about certain objectionable changes in butter, and that some chlorinated water may not be satisfactory for butter-making purposes. The use of absolutely clean water in making butter is a fundamental of great importance and should receive greater attention. P.A.D.

227. Sur Les Beurres Anormaux (On Abnormal Butters). P. Balavoine, Le Lait, *19:* 1027–1030. 1939.

This paper is a review of recent reports which deal with the significance of the Reichert-Meissl number and the refractive index as measures of butter purity. Such factors as changes in feed, stage of lactation, stable and atmospheric temperature, breed, etc., are suggested as causes of variation. An early hypothesis is revived that the source of butyric and other low boiling point fatty acid radicles present in milk, is the fermentation that takes place in the rumen of cattle. O.R.I.

CHEESE

228. Notes on the Preparation and Action of Rennet. J. G. Davis. Can. Dairy and Ice Cream J., *19:* 2, 56. 1940.

The rate of rennet clotting increases rapidly with small increases in the acidity of the milk. Albumin and globulin retard coagulation which is one of the reasons why mastitis milk clots slowly with rennet. Boiling the milk previous to adding the rennet removes the inhibitory effect. A rapid decline in rennet "coagulability" is observed after milk is taken from the udder. Desirable qualities in a good rennet are (1) constant strength, (2) good keeping quality, (3) freedom from fault-producing micro-organisms, and (4) freedom from other enzymes. Most samples of commercial rennet contain other enzymes but these should be kept to a minimum. O.F.G.

229. Studies of Starters for Cheesemaking. E. G. Hood. Can. Dairy and Ice Cream J., *19:* 1, 51. 1940.

The power to produce acid steadily throughout the cheesemaking process and at regular intervals from day to day is the most important property of

a good starter. In addition the culture should have good flavor and aroma. A small scale test for determining the vitality of cheese starters is described and the following precautions are given: (1) Use clean jars which have been sterilized, (2) Use one batch of milk for filling all the jars, (3) Stir the mother culture well before taking sample, (4) Measure 5 cc. starter accurately, (5) Measure 1 cc. of rennet accurately, (6) Mix both starter and rennet well with the milk, but do not overstir the rennet, (7) Cut the curd in all the jars to the same degree of fineness, (8) Keep the temperature of the bath constant at 100° F., (9) Drain the whey thoroughly at each stage and to an equal degree from each jar. The vitality test has the ability to differentiate between the acid-producing powers of starters when tested under similar conditions. O.F.G.

230. Cottage Cheese. D. W. GLOVER. Ohio State Univ., Milk Dealer, *29:* (6), 42. 1940.

A brief discussion of the influence of the following factors on the quality of cottage cheese:

1. The quality of the raw milk.
2. Pasteurizing temperatures.
3. The quality and amount of starter.
4. The amount of rennet enzyme used.
5. The acidity of the whey at the time the curd is cut.
6. The use of water to aid in cooking.
7. The rapidity of heating the curd.
8. Time and temperature used in cooking.
9. Temperature of wash water and number of washings.
10. Proper chilling of the curd before creaming.

The author also reports that homogenized milk returns may be utilized in the production of cottage cheese by the addition of calcium chloride, 1.0 cc. of a saturated calcium chloride solution per 100 pounds of milk being sufficient to restore the coagulating properties. C.J.B.

231. Les Formes Levures dans la Flore Superficielle des Fromage de Camembert. (Yeast Types in the Surface Flora of Camembert Cheese). G. GUITTONNEAU, J. KEILLING AND H. DE LAVAL. Le Lait, *19:* 338. 1939.

The organisms which produce the surface covering of Camembert cheese are thought to be very necessary for good flavor development. Samples of the surface slime were taken at intervals during the first 12 days of ripening from cheese manufactured in two Normandy factories. The flora were comprised of yeasts almost entirely with a few mycoderm and Odium colonies. The yeasts were largely of the Torula type.

A cultural study of the yeasts present showed that they were capable of digesting protein, fermenting sugar, and neutralizing acidity. Most strains

grew well on lactose, saccharose, glucose and levulose, some producing large amounts of alcohol, volatile acids and esters. A great majority of these strains were resistant to high concentration of salt and lactic acid.

O.R.I.

232. L'utilisation Économique du Froid Artificiel dans la Conservation et L'amelioration des Fromages a Pete Persillée. (The Economic Use of Refrigeration in the Holding and Curing of Mould Cured Cheese). A. MOULIN. Le Lait, *19:* 924–926. 1939.

Significant improvement can usually be affected where refrigeration is available for the curing of cheese of the Roquefort type. Two experiments are reported in which temperatures of 4–6° C. were employed. One part of a batch of cheese was tin-foiled and held at this temperature while the second portion was left unwrapped. Improved flavor, sharper color, more uniform texture and a lower loss from surface growth resulted in the case of the wrapped cheese. Earlier wrapping is possible where refrigerated storage is available. O.R.I.

233. Dosage de la Matière Grasse dans les Fromages. (Determination of Fat in Cheese). HENRI COUTURIER, Le Lait, *19:* 918–924. 1939.

Three methods of determining fat in cheese—volumetric (Gerber), direct extraction (Soxhlet), and indirect extraction (Schmidt)—are discussed from the point of view of accuracy and convenience. The author stresses the need for more fully standardized methods of sampling and also the fact that fat percentages vary with losses in moisture. The Schmidt method in which the solids-not-fat are first digested by hydrochloric acid possesses distinct advantages and can be rapidly carried out providing tared glassware is available to allow rapid weighing. No experimental values or comparisons are given however. O.R.I.

234. Les Fromages a la Crème. (Cream Cheese). J. M. ROSELL. Le Lait, *19:* 698–703, 811–814. 1939.

Manufacturing methods for several types of cream cheese common in Europe and America are presented in this review. Among the types discussed are the following: Double cream, sweet cream, English simple cream, Gervais cream, Fontainebleu, Italian or Mascarpone, Neufchâtel, Philadelphia and pasteurized cream cheese. O.R.I.

235. Theorie de la Maturation des Fromages Durs (Theory of the Curing of Hard Cheeses). S. ORLA-JENSEN. Le Lait, *20:* 2–16. 1940.

In a copyrighted feature article, the author traces the development of our knowledge of the biochemistry and bacteriology of cheese curing through the years, paying special reference to Swiss cheese.

Duclaux, the first director of the Pasteur Institute pioneered in this field and his work was followed by that of the Swiss bacteriologists Freudenreich, by Orla-Jensen and by the Austrian, Ademetz. As a result of studies made on "natural" rennet at this time, Christian Hansen began the manufacture of rennet commercially in Denmark in 1874.

Rennet was shown to be a source of proteolytic enzymes and the effect of acidity on proteolysis became the subject for study shortly after Sörensen developed his methods of determining hydrogen-ion concentration. The relation of proteolysis and pH to texture, first demonstrated by van Slyke, was an important contribution during this period. Extraction of the juice of cheese by pressure, in order to determine protein degradation was reported first in 1929.

Present-day knowledge of the volatile acids produced by lactic acid bacteria is based largely on the authors studies. The isolation and culturing of propionic acid bacteria in calcium lactate media has opened the way for much research on Swiss cheese problems. O.R.I.

236. Propionibacterium Rubrum from Dairy Cheese. LUBON A. MARGOLENA AND P. ARNE HANSEN, Royal Technical College, Copenhagen. Reprint, Zentr. Bakt. II, *99:* 107–115. 1938.

Propionibacterium rubrum van Niel has been isolated from a dairy cheese in which distinct colonies had been formed. A description of the species and pigment production is given.

The culture can be separated by means of the centrifuge in a pigmented and an unpigmented portion. The pigment is insoluble in the ordinary fat solvents, and is not, as previously assumed, a carotenoid. It is of no importance in the oxygen uptake of the organism. L.H.B.

CHEMISTRY

237. Recherches sur L'état Physicochemique des diverses Substances Lipoidiques du Lait et Particulariѐment des Phosphatides et du Cholestérol (Studies on the Physicochemical State of the Different Lipoid Substances in Milk and Particularly of the Phosphatides and of Cholesterol). F. TAYEAU. Le Lait, *20:* 129–134. 1940.

Other investigators have shown that the addition of sodium or potassium soaps to blood serum results in the liberation of additional fats not recoverable by direct ether extraction. These fats are present in the blood serum as part of the lecitho protein fraction.

This method has been adopted for the study of milk. The ether extracts are washed with distilled water and the ether then evaporated. After the weight of the residue has been determined, aliquots are analysed for phos-

phorus and for cholesterol, the latter determination being made by a colorimetric method.

The addition of small amounts of 20 per cent sodium linoleate solution to the milk at the time the ether was added, increased the efficiency of the extraction in the case of all three fat fractions—total fat, phosphatide and cholesterol. As the amount of soap solution was increased above 2.5 ml. per 100 ml. of milk the efficiency of extraction fell off rapidly. However, the curves for all three fractions were very similar. The author suggests that without the use of a soap solution in the extraction, approximately one-tenth of the total fat, three-tenths of the phosphatide and three-tenths of the cholesterol, are not extracted by ether alone. O.R.I.

238. Sur L'ammoniaque du Lait. (On the Ammonia of Milk). J. Heller and W. Swiechowska, Univ. of Wilno, Cracow, Poland. Le Lait, *19:* 1009–1016. 1939.

A method originally devised for the determination of ammonia in blood has been adopted by the above authors for the determination of ammonia in milk. Sodium borate is added to the sample, the ammonia is distilled off under reduced pressure, and the amount calculated from the Nessler reaction read in a photelometer. Fresh milk samples may be held for some time if the surface is covered with paraffin oil.

The source of significant increases in ammonia was found to be the result of the growth of micro-organisms, the amount present being an indication of the microbial content. The data presented indicate, however, that no great increase takes place in ammonia content until the bacteria count reaches figures in the millions. O.R.I.

239. Sur L'identification de la Grasse de Coco par le Methode du Dr. L. Hoton (The Identification of Cocoa Fat by the Method of Dr. L. Hoton). F. Livari, C. Mantovani, and E. Turco, Laboratory of Hygiene, Parma, Italy. Le Lait, *19:* 785–798. 1939.

The accurate identification of cocoa fat as an adulterant in butter is very difficult. Dr. Hoton of Belgium suggested the use of the refractive index of the insoluble volatile fraction obtained in the Reichert-Polenske distillation as an aid in its detection. In the formula

$$Q = \frac{VSA \times R.VIA}{10 \times VIA}$$

where values of Q equal or exceed 20, the absence of cocoa fat is indicated. Values lower than 15 indicate its presence. VSA refers to volatile soluble acids, VIA to volatile insoluble acids and R.VIA to the Zeiss index at 25° of the volatile insoluble acids.

The authors show that the method possesses disadvantages and suggest the use of the ratio $\frac{R.VIA}{VIA}$ in conjunction with the VSA value as a means

of analysis. Abnormal values due to feed are discussed and the failure of the method in the case of sheep's and goats' milk cheese is also shown.

O.R.I.

DISEASE

240. The Importance of Vitamin A in Animal Life and the Effect of Its Deficiency upon Animals. G. H. HART, Univ. of Calif., Davis, Calif. The Assn. Bull. Intern. Assn. of Milk Dealers. 32nd year: 13, 303–314. Feb. 1940.

Chlorophyll, carotene and xanthophyll, the several forms of carotene, and their relationship to Vitamin A are discussed. The storage of Vitamin A in fish livers from their phytoplankton diet is slow and in proportion to the age of the fish. An early experience with rancidity in milk due to Vitamin A deficiency is reported. The problem of determining the vitamin A value of a diet is complicated by the fact that a part of the vitamin A is preformed and a part consists of carotene transformed to vitamin A in the animal's body. The former is three times as effective per microgram as the latter so the proportion of each in the ration would need to be known. The unfavorable color effect of carotene upon meat fat and egg yolk is mentioned. Vitamin A deficiency results in temporary sterility and the birth of dead or weak calves. This is a very excellent discussion of the importance of vitamin A in animal life. E.F.G.

241. Vitamin A Deficiency in Man—Its Consequences and Methods of Detection. HAROLD JEGHERS, Boston Univ. School of Med., Boston, Mass. The Assn. Bull. Intern. Assn. of Milk Dealers, 32nd year. No. 13, 289–302. 1940.

The history of vitamin A is traced and its relation to night blindness, Xerophthalmia and infections shown. The better dietary sources of vitamin A are dairy products, liver, eggs and the highly pigmented vegetables and fruits. An instrument devised by Dr. Jeans measures night blindness which is caused by an impairment of the ability of the eye to replenish visual purple destroyed by bright light. Vitamin A deficiency in humans is tested by measuring this ability of the eyes. The Hecht and the Edmunds methods are also described. It is reported that students receiving 3,000 to 4,000 I. U. of vitamin A daily apparently had normal eye adaptation. Night blindness was caused experimentally by reducing the daily intake of vitamin A to 1/10 to 1/20 of the normal requirement. In eye impairment, the cone cells as well as the rod cells are affected, but not to as great an extent. A detailed case study is given of a student who must receive vitamin A from day to day as he could store only subnormal quantities in his body. This student given 100,000 units of vitamin A showed improvement

in night blindness in 40 minutes and at the end of 2 hours was normal. Three or four days served to render him subject to night blindness again. Persons deficient in vitamin A are also invariably subject to dazzling by bright lights. Adequate quantities of vitamin A for adults is given as 2,000 to 4,000 units and for children 6,000 to 8,000 units. A clinical procedure for diagnosis of vitamin A deficiency is given. E.F.G.

242. The Detection of Abnormal Cow's Milk by Microscopic Methods. S. HADWEN AND R. GWATKIN. Can. J. Res., *17:* Sec. D, 225–244. 1939.

In an attempt to establish standards for normal milk and furnish a basis for the more accurate diagnosis of mastitis, Breed and sediment smears were made on a large number of cows' milks. More information was obtained from the sediment count especially when the types of cells found were taken into consideration.

In staphylococcic mastitis the leucocytes are often very numerous, appearing as large, ring-shaped, polymorphonuclear cells. To a certain extent the resistance of the cow and the stage of infection can be estimated from the proportions of leucocytes and cocci present.

In streptococcic mastitis the mononuclear leucocytes are numerous, often in loose irregular clumps. In most cases leucocytes and cocci are not as numerous as in the staphylococcic type of infection.

The diagnosis of *B. coli* and *Corynebacterium pyogenes* mastitis is discussed as well as other phases of abnormal milk secretion including the significance of red blood cells, chromatin-staining granules and calcium concretions. O.R.I.

ICE CREAM

243. Reclaiming Butterfat from Homogenized Milk Returns. R. W. GREENWOOD. Can. Dairy and Ice Cream J., *18:* 12, 57. 1939.

A processing temperature of 145° F. appears to give the greatest efficiency of homogenization, pressure being constant, with the best possibilities for fat reclamation. Checks on the fat loss when homogenized milk was separated alone showed 1.1 per cent. Mixing homogenized milk with unhomogenized milk up to 20 per cent previous to separation does not merely spread the fat loss over the whole volume, but also improves the reclamation of the homogenized fat by approximately 20 per cent. The cream obtained from this procedure can be used in churning, and practically normal churnings of butter will be obtained. O.F.G.

244. Ice Cream Sales Index. ANONYMOUS. Special Bull. 63, Intern. Assn. of Ice Cream Mfrs., Washington, D. C. April, 1940.

This bulletin contains an analysis of ice cream sales for the year 1939, in comparison with the previous year.

The 1939 wholesale sales of ice cream increased 5.59 per cent over 1938. This means that 1939 was the biggest year in the ice cream industry, with sales exceeding 1938 by fourteen and a half million gallons, and 1937 by approximately 2,700,000 gallons.

The bulletin contains the ice cream production figures by states and sections of the country.

A supplement to the bulletin also gives monthly variations in production and employment. The decrease in production during the winter months is more severe than the decrease in employment. For example, December production is only 28 per cent of the July production while employment in December is 59.4 per cent of the July level. M.J.M.

245. Insulated Bags for Carry-Home Packages of Ice Cream. ANONYMOUS. Ice Cream Rev., *23:* 6, 42. 1940.

The Ice Cream Review conducted a survey to determine the extent to which insulated bags are used to protect carry-home sales of packaged ice cream. It was found that approximately 31 per cent of the wholesale manufacturers supply their dealers with the bags, while 54 per cent of the retail ice cream manufacturers use such bags. Other results of the survey are cited. J.H.E.

246. Lignin Vanillin Comes from New Source. ANONYMOUS. Ice Cream Field, *35:* 3, 53. 1940.

It is pointed out that lignin, derived from spruce and other conifers is now being used commercially as a source of vanillin. The two main sources of synthetic vanillin have been (1) the so-called guaiacal vanillin synthesized from benzol derivatives and (2) the so-called eugenol vanillin obtained from clove oil or cinnamon leaf oil.

The General Drug Company reports that the new extraction plant which has been operating less than two years already supplies about 50 per cent of the vanillin now being used in the United States. According to the report lignin vanillin is a product of high purity and is used widely by flavor and extract manufacturers that supply the ice cream, candy and baking industries.

The main steps in the process of manufacture of lignin vanillin are briefly outlined. W.C.C.

247. Dry Ice Truck Refrigeration. E. M. WESTBERG, Refrigeration Consultant. Ice Cream Field, *35:* 3, 35–39. 1940.

The author states that analysis shows that dry ice as an ice cream truck refrigerant has consistently gained ground, despite the fact that various mechanical systems have made marked progress. Mechanical and dry ice

systems have gained chiefly at the expense of ice and salt and cartridge systems. W.C.C.

248. Quality Control, Part II. V. C. STEBNITZ, Chicago Dairy and Food Laboratories. Ice Cream Trade J., *36:* 2, 26. 1940.

Part II of this discussion deals with the acid content of the ice cream mix, maintaining uniform composition, and the use of various non-dairy products constituents.

If neutralization is to be done it should never be carried to the extent of reducing the acidity below the normal acidity of the mix (about .19 per cent for a 10.5 per cent serum solids mix). The acid test as a measure of quality or freshness is limited by the fact that bacterial growth must take place to an appreciable extent before enough acid will be produced to materially affect the titratable acidity test.

It is important to test the mix for fat and solids. Although it may be more convenient in some plants to measure rather than weigh the liquid ingredients, more accurate results are obtained by weighing.

Although non-dairy ingredients do not spoil readily, their proper care is important in maintaining a low bacterial count. Quality control requires constant vigilance, not only from the control laboratory but for every one connected with the operations from the procurement of the raw material to the delivery to the consumer. W.H.M.

249. Practical Production. CHARLES POLICASTRO, Abbotts Dairies, Philadelphia, Pa. Ice Cream Trade J., *36:* 3, 26. 1940.

The following problems encountered in ice cream plant operation are discussed: (1) use of homogenized products for standardizing mixes; (2) the staggering of ice cream containers in the hardening room to provide proper air circulation; (3) selection of flavors; (4) use of dairy products of low natural acidity; (5) proper operation of the freezer; (6) importance of sanitation; (7) labor efficiency that will insure proper number of man-hours per unit of product; (8) elimination of waste and (9) proper planning of work, to make possible uniform power consumption. It is the author's belief that the ability of the plant operator to produce the largest amount of quality material per man-hour requires more than formulae and ingredients, it requires in addition to these, proper planning, cooperation of employees, alertness, and selling of ideas to the plant employees. W.H.M.

250. Freezing-point Data of Corn Syrup Solids. A. P. HELLWIG AND B. F. BUCHANAN, Technical Service Laboratories of the American Maize Products Co. Ice Cream Trade J., *36:* 2, 49. 1940.

Data is presented to show that solutions of corn syrup solids (Fro-Dex) have a higher freezing point than sucrose or dextrose solution of similar con-

centrations. The corn syrup solids is reported to contain dextrose, maltose, and edible dextrins in the approximate ratio of 15 : 43 : 42. W.H.M.

251. Factors in Low Temperature Refrigerator Bodies. T. J. HACKNEY, Hackney Brothers Body Co. Ice Cream Field, *35:* 2, 56. 1940.

The author outlines the requirements of good insulation and then discusses the more common systems of refrigeration in use on refrigerated trucks. He indicates that:

1. Where dry-ice is available economically, it provides the desired refrigeration at a minimum weight of apparatus or equipment.

2. Hold over plates are most economical when piped to a source of refrigerated gas through make and break valve connections. This system is suitable if the truck has a sufficient rest period between loads.

3. Bodies equipped with Freon or Methylchloride compressors permanently hooked-up with the hold-over plates are more satisfactory when the truck does not return to the plant each night, but will be where the desired power is available.

4. With exceedingly long runs and uncertain destinations continuous refrigeration may be taken from the truck chasis or may be obtained by a separate gasoline motor. The use of hold-over plates in a system of this kind may also be desirable.

The author claims that by the application of the above methods of refrigeration it is possible to solve the problems of low temperature truck operation. W.C.C.

252. Greater Plant Efficiency through Better Supervision of Delivery Equipment. E. A. KAYSER, St. Louis Dairy Co., St. Louis, Mo. Ice Cream Field, *35:* 2, 12, 13, 58, 59. 1940.

It is pointed out that delivery expenses of ice cream, exclusive of merchandising costs, amount to 56.8 per cent of total expense, whereas, it amounts to 34 per cent of the ice cream sales dollar.

With large scale operation he outlines the advantages in contracting for such items as gasoline, lubricating oils and greases, and tires.

He gives detailed instructions as to "the care of tires" and "garage technique," and reproduces the "Truck Preventive Maintenance Record" used by the St. Louis Dairy Company. W.C.C.

253. Interstate Barriers. W. H. LIST, Section New York and New Jersey, Ice Cream Manufacturers Assn. Ice Cream Field *35:* 2, 16, 62, 63. 1940.

Instances are cited in which legislative enactments have resulted in interstate barriers. Special mention is made of a recent law in Connecticut which

requires the pasteurization of ice cream mix within its borders, regardless of where or how it may have been previously pasteurized elsewhere.

The author reproduces several letters from state governors and United States Secretary of Commerce in an attempt to point out the seriousness of the problem. He suggests that legislators be encouraged to correct the condition. W.C.C.

254. Storage and Delivery Influence Ice Cream Quality. W. C. COLE, Division of Dairy Industry, University of California. Ice Cream Field, *35:* 2, 50. 1940.

Improvements in ice cream cabinets and delivery equipment make it much easier to control temperatures during delivery and storage. It is pointed out, however, that proper construction and insulation of the refrigeration compartments of trucks as well as adequate sources of refrigeration at suitable intervals are not sufficient to maintain the desired temperatures unless care is exercised by the operator in eliminating unnecessary opening of refrigeration compartment doors.

The new ice cream cabinets now in use are easily regulated and require relatively little service. The direct expansion type units have largely replaced brine filled limits and the cartridge systems formerly employed. He points out that cabinets used for factory filled packages are ordinarily set to operate at temperatures slightly below 0° F.

The author points out the advisability if not the necessity of the use of a checking system which should enable the manufacturer to check the quality of his product on the way from the plant to the ultimate consumer.

W.C.C.

MILK

255. A Discussion of Bottle Rinsing Problems. J. H. HALE. Can. Dairy and Ice Cream J., *19:* 2, 52. 1940.

Minimum recognized conditions for producing a satisfactory glass milk bottle are generally given as: (1) soaker solutions of at least 3 per cent alkali strength; (2) caustic content of at least 1.8 per cent; (3) maintained at a temperature of not less than 130° F.; (4) bottle immersion in the solution for not less than 5 minutes. When foam was not prevented the addition of a wetting agent to the soaker solution caused about 50 per cent greater residual alkali in the bottle compared to the non-foaming condition. High temperature of rinse water shows a greater efficiency of rinse. A slightly acidified rinse water was found to remove more residual organisms than a plain water rinse. The rinsing of mixtures of caustic with milder alkalies is for practical purposes, no different from straight caustic. The bacteriological problem is taken care of if the soaker solution is kept up to standard.

O.F.G.

256. The Consumer's View-Point. MRS. G. E. ROBINSON, Can. Dairy and Ice Cream J., *19:* 2, 19. 1940.

This article discusses some angles of distributor-consumer relationship which do not seem to have received recognition from many in the fluid milk industry. This consumer suggests that increased milk consumption holds as much interest to the housewife as it does to the producer and distributor.

O.F.G.

257. A Review of Milk Control in Ontario. C. M. MEEK, Can. Dairy and Ice Cream J., *19:* 1, 47. 1940.

This is a review article, which also points to the direction milk control may take under war-time conditions. O.F.G.

258. A Fundamental Factor. H. B. ELLENBERGER. Can. Dairy and Ice Cream J., *19:* 1, 15. 1940.

This article deals with the control of costs of production, assembly, transportation, processing, distribution and consumption. The author concludes that if milk could be produced and sold more cheaply, more would be used; the consumer would be benefited, profits to both the producer and distributor would be more certain and everybody concerned would be better satisfied.

O.F.G.

259. Types of Flavours Detected in Milk at the Receiving Platform. G. M. TROUT. Can. Dairy and Ice Cream J., *18:* 10, 41. 1939.

This is a report of a study of flavor the data for which was obtained by sampling 920 cans of milk as they arrived at the receiving platform. Approximately 45 per cent of the cans contained milk which was described as clean and pleasant to the taste. The flavors in the milk of the other 55 per cent of the cans were distributed as follows: feed, 43.19 per cent; musty, 19.92 per cent; high-acid, 14.37 per cent; unclean, 11.44 per cent; barny, 2.56 per cent; cowy, 2.37 per cent; oily, 2.56 per cent; miscellaneous, 3.55 per per cent. The author suggests that a change in feeding practices plus adequate cooling would eliminate much of the feed, musty and high-acid flavors which constitute over 75 per cent of the off-flavors present in these milks.

O.F.G.

260. The Elwell Plan of Sliding Scale of Prices to Consumers. EDWIN S. ELWELL, National Milk and Cream Co., Minneapolis, Minn. Milk Dealer, *29:* 6, 70–77. March, 1940.

A description of the Elwell plan whereby a sliding scale of prices is applied in the sale of milk and cream is presented. The plan is based on the fact that a certain cost is involved in the delivery of a quart of milk and that

additional quarts delivered at the same stop have a lower delivery cost. The benefit of this lower delivery cost is given to the consumer in the form of a lower price on additional quarts of milk. C.J.B.

261. Le Teneur en Matiére Grasse du Lait de Femme (The Fat Content of Woman's Milk). H. GOLTZ, Le Lait, *20:* 20–29, 145–154. 1940.

The quantity and composition of human milk are known to vary considerably as a result of many conditions. Fat content varies more widely than any other constituent. The literature in this connection is reviewed and the results of the author's studies at the Stuttgart clinic presented.

The relation of period of lactation to fat content indicates that there is a slight increase in fat content as the time advances. Samples taken on the third day *post partum* averaged 2.8 per cent and those from the second to the fourth month 4.2 per cent. There appears to be a slight but characteristic decrease on the tenth day, usually attributable to the resumption of body activity on the part of the mother.

The caloric value of initial milk compared to that of the final milk has been studied. In 85 per cent of the cases the final milk has a higher fat content although the differences in most cases was less than 0.5 per cent.

The results of 285 analyses, grouped on the basis of the age of the mother, indicated that age did not affect fat content. Goltz also found that the quantity of milk produced had little relation to its composition. This finding is contrary to those reported by other workers.

Evidence is presented to show that fever and inflammation markedly affect composition. In almost all cases, high temperatures resulted in an increase in fat content. In cases of serious mastitis the fat content is usually reduced. The age at which sexual maturity is attained also appears to affect the fat content, individuals reaching puberty at an early age tending to display a slightly lower fat content in their milk. O.R.I.

262. Comparative Investigations Regarding Goat Milk and Cow Milk. SIGURD FUNDER, Meieriposten, *29:* 4. Jan. 1940.

Experiments were conducted to determine the correctness or incorrectness of the contention that bacterial development is not the same in goat's milk as in cow's milk, and that cheese from the two milks do not ripen the same.

To minimize the errors that might be caused by differences existing in different individuals, large lots were used and the milk was obtained from different parts of the country and in different seasons. Milk from large and small herds has been used.

A resume of the experiment follows:

1. In general the goat's milk seems to have lower potential and real acidity than cow's milk (lower SH and higher pH). It usually has shorter

reductase time and larger catalase number, as well as larger contents of sediment and foreign substances. The bacterial content is on an average also greater and the fermenting types more undesirable than in cow's milk.

2. In the experiments it can be seen that in a few cases the goat's milk will sour slower than cow's milk but other times faster. There does not seem to be any constant quality in this respect. The milk flora in goat and cow milk varies both quantitatively and qualitatively and is determined by the direction the self inoculation takes.

3. The experiments seem to show that goat's milk contains, to a larger degree, thermiolabile material. This can be construed as bactericidal material.

4. By self inoculation the goat's milk regularly reached a higher acidity finally than cow's milk. This can be caused by microbial as well as non-microbial differences in the two milks.

Joel G. Winkjer.

263. The Use and Value of Special Tests in the Selection of Milk Salesmen. VERNE STEWARD AND ASSOCIATES. Los Angeles, Calif. The Assn. Bull. Intern. Assn. of Milk Dealers. 32nd year: 11, 251–263. Jan. 1940.

General principles which have been worked out for the selection of men likely to be successful in life insurance selling are applied to the selection of milk salesmen. The "series of hurdles" rating form is used to rate the applicants "unfit," "borderline," "acceptable" or "superior." Several factors are rated separately and weakness in anyone will cause the applicant to rate "unfit." The final hiring decision is, however, a responsibility of management. The Steward Composite Inventory and Examination suggests measures of mental ability; background knowledge; aggressiveness, initiative and leadership; stability; vocational interests. Several other characteristics are to be appraised by direct investigation. It is suggested that the selection of new employees has not received the attention it merits from the association and that a comprehensive field study over a period of months is needed to provide the basic material for a "Manual of Instructions" which would specify selection procedure. The article contained much valuable material with regard to employee selection. E.F.G.

264. Increasing the Viscosity of Cream. L. H. BURGWALD, Ohio State Univ. Milk Dealer, *29:* (6), 52–54. 1940.

A heat treatment for increasing the viscosity of cream is discussed. This method is to heat cream slowly to 84 to 86° F. in a vat, employing but little agitation. Take about one hour to heat. Then cool slowly (about 3/4 to one hour) to between 60 and 50° F. Draw off the cream in cans and store in ice water until the next day. Then standardize and bottle.

Using this method, an average increase of 8.3, 28, and 52.5 per cent was obtained in the flow time of 20, 22, and 25 per cent cream, respectively, as compared with untreated cream. C.J.B.

265. California Roadside Improvement Program for Dairy Farms. RALPH J. WHEELER, The Assn. Bull. Intern. Assn. of Milk Dealers. 32nd year. No. 8, 202–207. 1940.

An "Award of Merit" is given to a dairy farm which has achieved a score of 90, or above, under rules set up and administered by the California Dairy Industries Association. This movement, originating in the Los Angeles milk shed, has spead to other sections of California. The purpose is to make producing farms so attractive to passers-by that more milk will be consumed. In addition to the metal plaque to be placed on a post in front of the home a certificate suitable for framing is given. Many groups cooperate in fostering this movement. In the current year a dairy organization known as the Society of Yellow Dogs sponsored a Dairy Field Day which netted $550.00 for the benefit of this work. It is stated that pride taken in improved premises has resulted in many tenants becoming owners, that they might be putting this effort on their own places. E.F.G.

266. Present Trends in Milk Production in Relation to Future Prices of Dairy Products. G. E. GORDON, Univ. of Calif. The Assn. Bull. Intern. Assn. of Milk Dealers. 32nd year. No. 8, 196–201. 1940.

Attention is called to the necessity of operating on a high plane of efficiency in both production and distribution. It is suggested that we may have been considering as a normal dairy price level a price relationship in which dairy products have been comparatively high. The current production and consumption prospects are discussed. E.F.G.

267. The Milk Supply of Large Cities—Discussion of Methods for Safety. J. C. GEIGER AND B. Q. ENGLE, San Francisco, Calif. The Assoc. Bull. Intern. Assn. of Milk Dealers. 32nd year. No. 8, 187–195. 1940.

San Francisco's fluid milk supply is all of Certified or Grade A quality; is 100 per cent pasteurized and is produced on 190 dairy farms with an average of approximately 100 milking cows per farm. The maximum hauling distance is 131 miles and the average 42. The cream supply is also Grade A quality, produced on 297 farms averaging 60 cows per farm. The per capita consumption of milk is .54 pints and of cream .035 pints. The many sanitary and health requirements surrounding the production and handling of this milk including tuberculosis eradication are outlined. Structure requirements include a barn used exclusively for milking and a two-room milk

house. Milk must be cooled below 45° F. necessitating mechanical refrigeration. The logarithmic average of raw milk counts for 1926–27 was 25,000 colonies per cc. which was gradually reduced to 3,000 in 1938–39. The fat content of the milk has increased from 3.59 to 3.90 per cent during the same period. All milk and cream is brought raw to the 18 city pasteurizing plants. The logarithmic average of pasteurized milk in 1926 was 19,000 while the average for the past 6 years is under 450. Numerous more recent requirements for the market are listed. The author stresses the point that the plate count is a poor index of the milk flora and no index of the safety. The important characteristic of milk from the health officers viewpoint is safety. The answer to safety lies in field control of sanitation, field measures to keep out pathogenic organisms and in pasteurization. E.F.G.

268. Keeping Records for Determining Bottle Trippage. ANONYMOUS. Milk Dealer, *29:* 6, 34, 80. 1940.

A chart is presented, which is used as follows for determining bottle trippage: At the end of each filling period, mark number of bottles filled. At the end of each month put down total bottles bought. At the end of the year, divide the number of bottles bought into the number of bottles filled to find the number of trips per bottle. C.J.B.

269. Consumption of Chocolate Milk by Children. GIDEON HADARY, Univ. of Wis., Madison, Wis. Milk Dealer, *29:* 6, 33, 80. 1940.

From a study of the drinking habits of young children the following conclusions were drawn:

1. Children drink less milk as they grow older in spite of the fact that their preference for milk does not decrease.
2. Children shift away from milk drinking because of existing social and cultural influences.
3. Soft beverages are the substitute of the whole milk.
4. Chocolate milk is a beverage, and as such may come to replace the milk.
5. Consumption of chocolate milk does not decrease the total consumption of milk, due to the preference for the drink.The consumption of milk as a whole is increased. C.J.B.

270. Stop Sunday Delivery. ANONYMOUS. Milk Dealer, *29:* 6, 31. 1940.

In Akron, Ohio, as a step toward reducing distribution costs, Sunday deliveries have been eliminated. Time of delivery has been changed to begin at 7:30 A. M. instead of 5 A. M. Dealers report that sales have not suffered and that they have received hearty cooperation from the public. A big percentage of the milk sales in Akron is in gallon jugs. C.J.B.

271. **Cereal Cream.** PAUL VASTERLING, Sanitary Dairy Co., Indianapolis, Ind. Milk Dealer, *29:* 6, 30, 44–48. 1940.

The author advocates that cereal cream be used to compete with cream substitutes in order to improve the present low volume of cream sales.

The cereal cream contains from 10 to 12 per cent butterfat and 11 to 13 per cent of solids not fat, the additional solids being obtained from either skim powder or plain condensed. It is homogenized at high pressures, otherwise handled and processed much like ordinary cream. Because of the low fat content, cereal cream is sold under a trade name such as "Breakfast Special," etc. C.J.B.

272. **General Managerial Plant Problems.** WALTER C. SCHAFER, Borden's Dairy Delivery Co., Los Angeles, Calif. The Assoc. Bull. Intern. Assoc. of Milk Dealers. 32nd year, No. 9, 221–231. January, 1940.

The cost of change over of equipment in terms of labor requirements is calculated as 14 man hours per day when 10 different products were handled in addition to regular milk. The personal-injury frequency rate in all industries is 13.85 per million hours worked, in the food industry 16.79 and in the dairy industry 23.99. It is recommended that ample appropriations be made for carrying out an accident prevention program.

Many items of plant procedure are mentioned which aid in eliminating public health hazard. It is recommended that all prospective employees be given an adequate physical examination before they are finally employed to determine if they are able to meet the physical requirements of the industry and turn out a full day's work without hazard to themselves or fellow workers. The employee should have periodical physical examinations to keep him healthy and efficient. Such health supervision saves the company more than it costs. Several graphs show that more accidents occur on Monday than any other day, that February and September are the high accident months, handling objects causes more accidents than any other cause, that haste and lack of alertness are responsible for larger number of injuries and that of all parts of the body the fingers are most frequently hurt. E.F.G.

273. **Proper Assembly of Fittings and Fabrication of Milk Lines.** E. N. MUZZY, Samark and Co., San Francisco, Calif. The Assoc. Bull. Intern. Assoc. of Milk Dealers. 32nd year, No. 9, 215–220. January, 1940.

The present tendency is away from many crosses and tee fittings and toward simpler layouts, including one piece fittings and the new type threaded sweep ells. Under the direction of the Simplified Practices Committee of the International Association of Milk Dealers equipment design

has been both improved and standardized. The expanded and flared type of fitting has come with stainless steel and eliminated a great deal of poor soldering. An actual plant layout was shown and the piping was installed first in a modern satisfactory manner and then later, showing "horrible" examples of poor type of fittings and improper assembly. E.F.G.

274. **A New Method of Preparing Churned Cultured Buttermilk.** GEORGE B. SAUER, Lucerne Cream and Butter Co., Los Angeles, Calif. The Association Bulletin, Intern. Assoc. of Milk Dealers. 32nd year, No. 9, 211–214. January, 1940.

A centrifugal pump is used instead of a butter churn to produce butter granules. The standard procedure for producing churned cultured buttermilk is followed till churning time. In winter it may be necessary to warm the ripened milk to 75 to 76° F. before pumping. A 2-inch pump turning at 1500 r.p.m. is used discharging the culture 10 or 12 inches above the surface or preferably using a concussion chamber to provide a uniform drop. Ten minutes per 100 gallons of buttermilk is usually needed. It is stated that this method produces a slightly thinner body than the regular churn method but this can be controlled by adjusting the per cent of solids not fat. Advantages claimed for the method are lower investment, the whole process carried out in one piece of equipment, better quality because the unsanitary churn is eliminated and also the size of granules can be more easily controlled. A rather complete description of the entire process is given.

E.F.G.

275. **Contributions à l'Étude du Calcium du Lait. (Contributions to the Study of Calcium in Milk.)** R. VLADESCO. Le Lait, *19:* 354. 1939.

The lack of agreement which exists in the older literature among values pertaining to the mineral matter of milk is understandable in the light of modern theories of ionization. Thus the quantity of calcium held by casein as a caseinate is dependent upon the reaction of the medium. In an alkaline medium very little calcium is held in the colloidal caseinate form.

This fact can be taken advantage of in determining calcium in milk without the necessity of drying or ashing the sample. Ten ml. of milk are diluted with about 70 ml. of water and the protein precipitated with copper sulphate and potassium ferrocyanate. After making up to 100 ml. the mixture is filtered and 25 ml. of the filtrate analysed for calcium by the ammonium oxalate-potassium permanganate method. O.R.I.

276. **Le Lait et La Vitamine C en Roumanie (Milk and Vitamin C in Rumania).** R. VLADESCO AND MLLE H. PRAHAVEANU. Le Lait, *19:* 798–806. 1939.

The role of vitamin C in physiological oxidations and in the treatment of

diseases of the alimentary tract is discussed. In view of the fact that human infants sometimes have to secure part of their vitamin C from cows' milk, extra care should be exercised to prevent its destruction. Data are presented to show that the cause of variation in the vitamin C content of raw milk is largely atmospheric oxidation. The average value was 16.32 mgm. per litre with a range of from 8.07 to 29.24 mgm. per litre. O.R.I.

277. **Factors Related to Viscosity Control.** E. WALLENFELDT, Extension Specialist in Dairy Industry, Univ. of Wis., Madison, Wis. Milk Dealer, *29:* 5, 70–74, 83–84. Feb. 1940.

The effect of butterfat content, temperature, breed of cow, separating temperature, pasteurizing temperature, aging, cooling time, homogenization, and special temperature treatment, on the viscosity of cream were studied. The following conclusions were drawn:

1. Pasteurization temperature of 143–145° F. gives higher viscosity than higher temperatures with the holder method for 30 minutes.

2. Aging for 24 hours before sale seems desirable from the standpoint of viscosity control.

3. Accurate and uniform fat standardization is important.

4. Cream should be delivered at as low temperatures (above 32) as is practical.

5. Agitation between the temperatures of 90 degrees F. and 40 degrees F. should be as gentle and as uniform as possible.

6. Slower rate of cooling will cause increased viscosity.

7. If local health regulations and plant facilities permit, a viscous cream may be produced by separation of pasteurized milk (at 80–85 degrees F.) which has been held for several hours after pasteurization.

8. Cream of very satisfactory body can be produced by homogenization. C.J.B.

278. **Thermophilic Bacteria in Pasteurized Milk.** CHARLES C. WALTS. Res. Assoc. Creamery Package Mfg. Co. Milk Plant Monthly, *29:* 4, 29. 1940.

Thermophilic "heat loving" bacteria are often responsible for high count "pin point colonies" on plated pasteurized milk. Three laboratory methods; namely, agar plate, direct microscopic and methylene blue and resazurin reductase, have been used to determine whether thermophilic or thermoduric organisms are responsible for high counts and pin point colonies. Control procedures involve quality production procedures on the farm, particularly adequate cooling, and in the plant checking such factors as cleanliness and sterility of cans, deposits of milkstone, cleaning, sterilizing and drying of equipment, repasteurization of milk, long continuous pasteurization, long use of same filter cloth, foam on milk, dead ends of sanitary piping,

allowing milk to remain hot in preheaters and permitting condensation from unsterile surfaces to drop into pasteurized milk. G.M.T.

279. **Chocolate Milk.** J. G. Brereton, W. B. Combs, and H. Macy, Dairy Division, Univ. of Minn., St. Paul, Minn. Milk Dealer, *29*: 5, 38, 62–68. Feb. 1940.

From a study of the factors influencing the physical characteristics of chocolate milk the authors draw the following conclusions:

1. With the exception of one powder and one hot-process syrup, all of the commercial non-settling chocolate milk preparations studied produced a stable chocolate milk when the processing recommendations of the manufacturer were followed.

2. Slow cooling of chocolate milk in the vat will cause cocoa sedimentation if the milk is on the borderline of complete stability as judged when the milk is surface-cooled.

3. Increasing the fat content of the milk used to make non-settling chocolate milk will decrease the amount of cocoa sedimentation when instability results with a milk of a low fat content.

4. With commercial, non-settling preparations, the temperature of the milk at the time of adding the powder or syrup does not affect stability, provided the agitation in the vat is satisfactory and the material does not contain an alginate stabilizer.

5. Increasing the temperature of pasteurization decreases the amount of stabilizer needed to produce a stable chocolate milk.

6. In making non-settling chocolate milk by the cold-process syrup method, adding the syrup to milk as warm as 75 degrees F. does not impair the stability of the chocolate milk and may be considered advantageous because it facilitates the dispersion of the syrup in the milk.

7. Colorless, odorless and practically tasteless stabilizers are available for making chocolate milk.

8. The physical state of certain stabilizers in water suspension is greatly affected by the presence of relatively low concentrations of certain salts.

9. The addition of small amounts of $CaCl_2$ to milk causes the gelation of a purified alginate stabilizer in that milk.

10. In general, chocolate milk made with algal stabilizers has a tendency to thicken upon aging at 40 degrees F. as evidenced by the increase in the body flow time.

11. The presence of algal stabilizers in milk can be shown by staining the milk with a dilute aqueous solution of crystal violet.

12. When chocolate milk is pasteurized at 165 degrees F. for 20 minutes, the minimum amount of the various stabilizers needed for complete stability has been shown to vary from 0.036 per cent up to 0.245 per cent of the weight of the milk used.

13. "Natural" process cocoas could not be used satisfactorily to prepare stable chocolate milk with the alginate types of stabilizer now being sold.

14. When stabilizers are used to prepare chocolate milk, the cocoa fat content and the relative fineness of the average commercial cocoa do not seem to have any appreciable effect upon the stability of the chocolate milk.

C.J.B.

280. Standardize New Two-Quart Bottle. ANONYMOUS. Milk Dealer, *29:* 5, 37. Feb. 1940.

A joint meeting of the glass container, cap, equipment, and crate industries passed the following resolution:

That a standard two-quart bottle be adopted for the dairy trade with the following specifications:

Height	10½ in.
Body Diameter	4–25/32 in.
Weight	30 oz.

C.J.B.

281. Towards a Perfect Milk Market. J. ELIZABETH DONLEY. Mass. Agr. Exp. Sta. Bull. 366.

The bulletin reports a study of the milk supply for the city of Worcester, a secondary milk market in Massachusetts. An analysis of the supply, methods of payment and sales of milk for the year 1935 is made. The conclusion was that an equilibrium of supply and demand, practically speaking, had been established. If any part of the channels then existing should be changed, the amount of surplus would doubtless increase.

The transportation phase seems to be the only part which might be more efficiently organized but that involves personal relationships and should not be regulated by the Massachusetts Milk Control Board.

There is really nothing radically wrong in the market set-up, at least in the supply side of it. The producer sells his milk regularly throughout the year, the dealer has very little surplus to dispose of, and the consumer is assured of a regular supply of good milk throughout the year. H.G.L.

282. The Control of Sediment in Homogenized Milk. A. J. HAHN AND P. H. TRACY, Dept. of Dairy Husb., Univ. of Ill., Urbana, Ill. The Dairy World, *18:* 10, 28. Mar. 1940.

Homogenized milk held cold (40°–45° F.), without excessive agitation, will be free of sedimentation if the cell count is under 100,000 ± 25,000. If the temperature increases after bottling and if the bottles have been subjected to agitation, then a cell count of 50,000 or less is needed to avoid sedimentation. Clarification is almost essential if the cell count is in excess

of 125,000 in milk to be homogenized. Clarification following homogenization is more efficient than previous to homogenization and multiple clarification is more efficient than single treatment. Destabilization of the milk protein will increase sedimentation and vice versa. F.J.D.

MISCELLANEOUS

283. The Choice of Fuel for a Dairy Plant. S. KONZO. Can. Dairy and Ice Cream J., *19:* 2, 44. 1940.

The author outlines 14 points to be observed in obtaining maximum combustion efficiency of the fuel in use. The choice of the fuel to be used in any given case is a matter to be decided ultimately by the plant owner.

O.F.G.

284. Some Facts about Merchandising Quick Frozen Foods. C. Q. SHERMAN. Can. Dairy and Ice Cream J., *18:* 12, 43. 1939.

Quick frozen foods are economical and are better than when fresh. Ice cream manufacturers should be interested in quick frozen foods because they are a "natural" for distribution by the industry. The best type of outlet is the grocer or meat dealer catering to the average wage earning element. Frozen foods must be displayed so as to show how natural they appear. Suggestions as to equipment loans, insurance and margin for the distributor are given. O.F.G.

285. Creating Consumer Demand. F. BEACH. Can. Dairy and Ice Cream J., *18:* 10, 15. 1939.

This is a discussion of present day advertising and suggestions are given as to how the best trends in presenting products to the consumer can be used. The author suggests that a judicious combination of research, proper development of customer good will, constant insistence upon cooperation and coordination within the industry, effectively presented by means of an intensive advertising campaign will create a satisfactory consumer demand.

O.F.G.

286. Nouvelle Application de la Lampe de Quartz à Haute Tension à Vapeur de Mercure Irradiation des Eaux D'alimentation des Chaudières pour Empêcher L'entartrage (New Application of the high tension quartz-mercury-vapour lamp to boiler feed water to prevent scaling). J. VIEILLY. Le Lait, *20:* 142–145 1940.

Water which normally produces a hard, rust-colored scale when evaporated in a boiler, can be treated by irradiation so as to yield a soft type of boiler mud that can be easily removed. Water subjected to this type of

treatment and used for several months will gradually clean up a scaled-up boiler. The author presents no figures as to the type of hardness present in the raw water, however.

The above results are discussed and the possible relationship between irradiated and "Scale-Buoy" treated water pointed out. The question is raised as to whether or not irradiation may not significantly affect the state in which calcium and other minerals are held in milk. It is also suggested that the anti-rachitic potency of such milk may be in part due to the activation or ionization of the calcium. O.R.I.

287. Address of the President at the Thirty-Second Annual Convention. F. F. RENNIE, JR., Virginia Dairy Co., Richmond, Va. The Assn. Bull. Intern. Assn. of Milk Dealers. 32nd year: 10, 237–248. Jan. 1940.

The growth of the association from 62 members twenty-four years ago when it also met in San Francisco is reviewed. Trends in the industry and activities of the association committees during the past year are summarized. Reference is made to the objectives of the association and measures being taken to attain them. Attention is drawn to the fact that milk sold at lower prices than home delivered milk does not increase consumption, but that higher consumption results from home delivery to the ultimate benefit of the consumer. Recommendations are made with regard to activities which should be pushed during the coming year. E.F.G.

288. Pacific Slope Dairying—Before 1850. ROBERT E. JONES. Pacific Dairy Review, *43:* 10. 1939.

The first cattle in many numbers came to California in 1769. At Carmel Mission, milk was practically the only food for eight months, but for the most part there was an immense number of cattle and very little milk. The cattle were valuable for their hides and by 1834 there were over 400,000 of them being raised.

Cattle made their way into Oregon and were divided among the settlers. Jason Lee helped those settlers, who could afford to pay cash, to find ways to get cattle. Ewing Young and several others drove nearly 700 cattle to Oregon. Indians were a menace during the drive.

Development of dairying in Idaho waited until the coming of irrigation. Reverend Colton thought that there was not much possibility for agriculture and dairying in California, but today California stands in second position among all the states in the value of agricultural products. P.A.D.

289. Pacific Coast Dairying During the Gold Rush—Article II. ROBERT E. JONES. Pacific Dairy Review, *43:* 12. 1939.

Jacob Harlan was considered the first San Francisco distributor of milk.

In 1850 he bought some cows and employed a man to sell the above mentioned product at four dollars a gallon.

The feeling for improved stock was great in the early fifties; therefore, little regard was given to the preservation of the native breed. Robert Blakon was extensively engaged in the importing and breeding of fine livestock.

The cows driven across the plains were the foundation of dairy efforts, for the growth of dairying after 1850 was rapid. By 1860 the eastern rim of California was well populated by the offspring of the pioneer cows and the production of dairy products was a growing industry. P.A.D.

290. Modern Methods of Fly Control. W. A. POHLMAN, Milk Dealer, *29:* 6, 40, 64–68. 1940.

A discussion is given of fly control from the standpoint of prophylactic methods and plant openings. The prophylactic methods apply to the territory adjacent to and surrounding the plant property and in the plant proper. The plant openings are discussed from the standpoint of proper closures, erection of barriers, and elimination of unnecessary openings. C.J.B.

291. Recharting Your Plant for More Efficient Steam Operation. H. A. MOON. Milk Dealer, *29:* 5, 30–32, 57–61. Feb. 1940.

A detailed description of how to chart plant operations. This is followed by instructions for recharting the plant so as to avoid danger points. Examples are given where recharting eliminated the necessity of purchasing a larger boiler. The chart is also applicable for the lighting, power, labor, refrigeration, and water used in any given plant. C.J.B.

292. Clean Dairy Products. L. M. DORSEY, Univ. of Maine. Ice Cream Trade J., *36:* 3, 53. 1940.

The advantage of water lubricated pumps over oil lubricated pumps for water supplies for food production is pointed out. W.H.M.

293. Maintaining Plant Efficiency. H. S. FIELDER, Cherry-Burrell Corp., Chicago, Ill. Ice Cream Field, *35:* 2, 20, 22, 74, 75. 1940.

It is pointed out that most people realize the value of proper plant layout, but too frequently they fail to see the need for replacing or remodeling obsolete and worn out equipment.

In the installation of new equipment or the remodeling of a plant it is necessary to check many details which might otherwise fail to be properly handled. Special mention is made of steam and refrigeration.

It is claimed that upkeep and maintenance are fundamental in obtaining good operating efficiency in any plant, but especially in a dairy plant.

Proper maintenance will keep "shut-downs" to a minimum. He advises the proper filing of instructions for maintenance, lubrication, etc., for each piece of equipment which will help prevent difficulties and will help eliminate them if they occur.

May other regularly recognized practices are mentioned in relation to economical plant operation, e.g., noncondensable gases in the refrigeration system raise the head pressure, oil in the evaporators requires lower back pressures at the compressor in order to accomplish the cooling desired.

W.C.C.

PHYSIOLOGY

294. The Comparative Anatomy of the Mammary Glands (With special reference to the udder of cattle). CHARLES W. TURNER, Univ. Cooperative Store, Columbia, Mo. 373 pages, illustrated.

This book is designed primarily as a text for college students of agriculture (dairy and animal husbandry), veterinary science, biology, and medicine. Investigators in these fields will find the book an excellent reference text.

A valuable feature of the book, especially for research workers, is the extensive bibliography following each chapter. For the student the questions with each chapter will prove stimulating in ascertaining his knowledge of the chapter.

The work consists of the following 5 parts: Part I, The Gross Anatomy of the Mammary Glands of Cattle; Part II, Microscopic Anatomy of the Udder of Cattle; Part III, The Comparative Anatomy of the Mammary Gland; Part IV, Anatomy of the Mammary Glands of the Hoofed Mammals (*Ungulata*); and, Part V, The Anatomy of the Mammary Glands of the Primates.

This book is well written and admirably illustrated with 54 full-page plates and 14 charts and diagrams. It is unique in having as a source of so much of its material the work of the author. R.P.R.

295. Hormonal Inhibition of Lactation. R. P. REECE, J. W. BARTLETT, I. L. HATHAWAY, AND H. P. DAVIS, Depts. of Dairy Husbandry, N. J. Agr. Exp. Sta. and Nebr. Agr. Exp. Sta. Proc. Soc. Exp. Biol. and M., *43:* 183. 1940.

Fifty-six lactating rats were used in this study. An estrogen (Progynon-B) and a gonadotropic principle from pregnant women's urine (Antuitrin-S) were administered separately and also simultaneously. The effectiveness of Progynon-B in inhibiting lactation was increased through the simultaneous administration of Antuitrin-S. Many cells in mitoses were observed in the mammary gland parenchyma of rats so treated. Progynon-B, either alone or with Antuitrin-S, augmented the lactogen content of the pituitary gland. R.P.R.

296. Further Evidence for a Mammogenic Factor in the Rat Hypophysis. RALPH P. REECE AND SAMUEL L. LEONARD, Dept. of Dairy Husbandry, N. J. Agr. Exp. Sta., and the Bureau of Biol. Res., Rutgers Univ. Proc. Soc. Exp. Biol. and M., *42:* 200. 1939.

It was possible to demonstrate an "hypophyseal factor" in rats of both sexes which was capable of inducing growth of the mammary glands in castrated hypophysectomized immature female rats. The administration of estrogens did not influence the "mammogenic factor" when tested in hypophysectomized rats, however, the treatment was sufficient to lower the growth-stimulating power of the hypophyses. R.P.R.

297. Lactogen Content of Female Guinea Pig Pituitary. R. P. REECE, Dept. of Dairy Husbandry, N. J. Agr. Exp. Sta., Proc. Soc. Exp. Biol. and M., *42:* 54. 1939.

The lactogen content of pituitary glands from 48 guinea pigs sacrificed either in estrum, diestrum, early pregnancy, late pregnancy, or the 11th day of the lactation period was determined by injecting the suspended tissue intradermally over the crop gland of common pigeons. The lactogen content was lowest during diestrum and highest during lactation while the glands from guinea pigs in estrum contained more lactogen than did those in early pregnancy and less lactogen than did those in late pregnancy. R.P.R.

298. The Respiration of Human Spermatozoa and Their Response to Various Gases and Low Temperatures. LANDRUM B. SHETTLES, Dept. of Obstetrics, Johns Hopkins Univ. and Hospital. Am. J. Physiol., *128:* 408–415. 1940.

Carbon dioxide produces complete immobility of human spermatozoa within a few minutes. Motility can be restored if the carbon dioxide is replaced by nitrogen, air, or oxygen as soon as all movement ceases. The toxic effect of the gas is dependent neither upon its acid character nor upon anoxia. Nitrogen, nitrous oxide, and air reduced to a very low pressure do not decrease the motility of the spermatozoa. Helium and pure oxygen increase motility. No data are given relative to the effect of these treatments on the fertilizing ability of the spermatozoa. D.E.

299. Die Entwicklung des schwarzbunten Niederungsrindes von der Geburt bis zum 5. Lebensjahr und variationsstatistische Untersuchungen einer Population solcher Rinder von der Geburt bis zum. 3. Lebensjahr. ALOYS OTT. Ztschr. f. Tierzücht. u. Züchtungsbiol., *45:* 3, 259–308. 1940.

At the University of Breslaw 121 cattle were measured regularly from birth to the age of three years and 34 of these were measured to five years.

Nine measurements besides weight were taken at birth, then monthly during the first year, then quarterly during the second year, then at 2.5 years, and finally at three, four and five years. Measurements are given in absolute numbers, relative to wither height, relative to their initial value, and relative to the values at five years. The discussion includes growth rates, individual and racial differences, and the changing conformation of the animal with age. Standard deviations were computed on the larger group and considerable stress is laid on the coefficient of variation in interpreting growth changes. J.L.L.